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OUTSTANDING FEATURES OF PETROLEUM DEVELOPMENT IN AMERICA[1]

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I. EARLY DISCOVERIES AND USES OF PETROLEUM

OLD WORLD

The part played by petroleum in advancing civilization began some thousands of years, at least, before the Christian era. Accounts of the occurrence and uses of oil or its solid residues appear in many ancient writings on natural history, travel, religion, and philosophy. From these earliest sources of scientific information it is evident that we are far beyond the day when oil and gas, maltha, the semifluid residue, and asphalt had first been noticed in one country or another and put to use. Most interesting compilations of these early accounts have been made at different times by various authors, and one of the most scholarly and comprehensive is that prepared by S. F. Peckham[2]

[1] In pursuance of House Resolution 441, 73d Congress (Recess) a Subcommittee of the Committee on Interstate and Foreign Commerce was appointed to investigate various phases of the petroleum industry. Part II of the Hearings of this Subcommittee is a volume of technical papers contributed by members of the United States Geological Survey and the United States Bureau of Mines. The first division of Part II covers "Geology and Occurrence of Petroleum in the United States," by the United States Geological Survey.

The number of copies of Part II of the Hearings printed is insufficient to give them general distribution, and the executive committee has authorized the reprinting in the *Bulletin* of Sections 1 to 6, by David White, on account of this fact and because of their general interest and value to petroleum geologists. These sections are reprinted by arrangement with the Subcommittee on Petroleum Investigation, the director of the United States Geological Survey, and the author. Small portions of Section 6 that give historical notes on many states are here omitted in compliance with request of author. —L. C. Snider, editor.

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[2] S. F. Peckham, "Production, Technology, and Uses of Petroleum and its Prod-

and his collaborators. Of this valuable work, and especially of the translations of early writings, the writer has made very free use, in many cases without acknowledgment.

According to the Biblical narratives, the Ark built by Noah was "covered with pitch [asphalt] within and without." The cradle of Moses was calked with asphaltic pitch, as are the boats on the Euphrates at the present day. "The Vale of Siddim was full of slime [bitumen] pits."[3]

Again we learn[4] that the fire that had been taken from the altar and hidden in a deep dry pit by the priests was found long afterward, by the sons of the priests whom Nehemiah sent to recover it, to be no fire, but "thick water." The prophet poured this upon the sacrifice, the wood, and the altar, and when the sun came out it burst into flame and

> a great fire was kindled and Nehemiah called this thing "Napthar"; which is as much as to say a cleansing; but many call it "Nephai."[5]

In exhuming the buried cities of Ur, which antedated Babylon, archeologists have found that asphalt was used as far back as the structure below the "diluvial" layer, probably easily as early as 4000 B.C.

Herodotus,[6] writing about four and a half centuries before the Christian era, described the mode of recovery and use of pitch from a spring in a lake on the island of Zante, in the eastern Adriatic, off the coast of Albania, and Ctesias described the gas springs of Karamania. Herodotus says that at the largest springs in Zante the natives let down a pole with a myrtle branch fastened to the end, and drew up the pitch adhering to the myrtle. After accumulating a sufficient quantity in a cistern it was poured into jars.

Most celebrated in the Near East were the occurrences in Mesopotamia and in the vicinity of the Caspian Sea, the neighborhood of Baku, in particular. The famous "fountains of Hit" (Oyun Hit), known also to the Arabs and Persians as the "fountains of pitch"

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ucts," *Tenth Census*, Washington, 1884. Adequate citations of the original literature and more copious extracts or translations will be found in Peckham's invaluable contribution.

[3] See *Genesis*, 6: 14; *Exodus*, 2: 3; *Isaiah*, 34: 8, 10; *Genesis*, 14: 10.

[4] *Maccabees*, book 2, 1: 18–36.

[5] The term "naphtha," much used also in present-day Old World literature, is the "Nafta," a word of unknown antiquity, used by the Syrians, Persians, and other peoples of the Near East.

[6] Herodotus, lib. 4, p. 195; trans. in *Soc. géol. France Bull.*, Vol. 25, p. 62.

(Chesmeh Kir), are believed to have been the sources of the bitumen used in building the tower of Babel. Herodotus remarks:[7]

> Eight days' journey from Babylon stands another city, called Is, on a small river of the same name, which discharges its stream into the Euphrates. Now this river brings down with its water many lumps of bitumen, from whence the bitumen used in the wall of Babylon was brought.

All the bricks of the pavement of the city were stamped with the name of Nebuchadnezzar and were laid either in asphalt or in gray lime mortar. Among the inscriptions are these: "I caused a mighty wall to be built on the east side of Babylon. I dug out its moat and I built a scarp with bitumen and bricks." "I built a palace (Babil) of brick and bitumen." "I . . . placed above the bitumen and burnt brick (road) a mighty superstructure of shining dust, and made them strong within with bitumen and burnt brick as a high-lying road."[8] This seems the earliest record of the use of asphalt in paving.

Speaking of the pits dug about natural springs at Kir ab ur Susiana, Herodotus[9] writes:

> At Ardericca is a well which produces three different substances, for asphalt, salt, and oil are drawn up from it in the following manner: It is pumped up by means of a swipe, and, instead of a bucket, half a wine skin is attached to it. Having dipped down with this, a man draws it up and then pours the contents into a reservoir, and, being poured from this into another, it assumes these different forms: The asphalt and the salt immediately become solid, but the oil they collect, and the Persians call it "rhadinance"; it is black and emits a strong odor.

This description of the separation of the pure oil from the asphalt and inorganic impurities records a primitive stage in the process of oil refining. The Turks gave the pitch, as distinguished from the liquid naphtha, the term "hara sakir," meaning black mastic.

From these and later accounts we learn that—

> the semifluid bitumen was used in the construction of Nineveh and Babylon to cement bricks and slabs of alabaster, and the grand mosaic pavements and beautifully inscribed slabs used in the palaces and temples of those ancient cities, many of which were of enormous size, were fastened in their places with this material. It was also used to render cisterns and silos for the preservation of grain water-tight, and some of these structures of unknown antiquity are still found intact in the ancient cities of Egypt and Mesopotamia.

In 1840 Ritter records:

[7] Herodotus, lib. 1, p. 179; *Soc. Arts Jour.*, Vol. 7, p. 639.

[8] Robert Koldeway, *The Excavations at Babylon*, (1914), pp. 11, 12, 5

[9] Herodotus, lib. 6, p. 119.

The naphtha is more highly valued than the solid bitumen, the most fluid varieties being used in lamps. . . . The Persians also manufacture dried dung in long sticks, which are dipped in naphtha and burned for lights, and it is also used for cooking and heating; but in order to avoid the unendurable smell a peculiar kind of chimney is carried into each room. Cotton wicks are also used in naphtha to some extent. The white or colorless naphtha, which is most rare, is used by the apothecaries.[10]

The use of petroleum as a binder for dried dung foreshadows its later somewhat extensive use in the western countries as a binder of coal particles in the manufacture of briquets.

When visiting the vicinity of Kerkuk, in Mesopotamia, Alexander, according to Plutarch, became deeply interested in—

a gulf of fire, which streamed continually as from an inexhaustible source. He admired also a flood of naphtha not far from the gulf, which flowed in such abundance that it formed a lake. The naphtha in many respects resembles the bitumen but it is much more inflammable. Before any fire reaches it, it catches light from a flame at some distance and often kindles all the intermediate air. . . . Still there remains a difficulty as to the generation of this naphtha, whether it derives its inflammable quality from [word missing in the original], or rather from the unctuous and sulphurous nature of the soil.

Both Strabo, who describes the occurrence of bitumens in the Valley of Judea[11] and the manner of occurrence of the asphalt on the surface of the Dead Sea, forming masses resembling islands during and after earthquake shocks, and Diodorus,[12] of Sicily, describing the lake asphalts used by the natives in constructing rafts, report the development of commerce in asphalt with the Egyptians, who began the use of asphaltic pitch in the process of mummification as long ago as the fourth dynasty (about 3500 B.C.). Hence, the Egyptian name from Syria "mumia," for asphalt.

The inscription accompanying a mummy dating from one of the early dynasties reads:

May Thoth, lord of the words of the gods, president of all the gods, grant exit from and entrance into Khert-Neter . . . . May Osiris, lord of Ta Tchesert give meat, and drink—and bitumen oil, and every good and pure thing to the Ka of . . . .

A celebrated Arabic physician, Ibn Betar, who died about 646 A.D., says that "mumia" is found in the country called "Appolonia," where it flows down with water from the "lightning mountains" and

[10] Peckham's summary from Carl Ritter's *Die Erdkunde, von Asien*, Vol. 2 (1840), p. 578.

[11] Strabo, lib. 16, 112.

[12] Diodorus, tome 1, livr. 2, cap. 29.

is deposited by the water on the sides of the watercourses. There it becomes hard and thick with an odor like that of pitch. He explains that "mumia," or the bitumen of Judea, is a mixture which the Byzantine Greeks used formerly for embalming their dead . . . and is obtained from Asphaltites Lake.[13]

Budge notes that—

> Under the later dynasties of the new kingdom a very large number of bodies were turned into mummies by being dipped, bandages and all, into bitumen. . . . It was this class of mummy which the natives of western Thebes broke with hatchets and used as fuel.

Budge further states:[14]

> About 300 to 400 years ago Egyptian mummies formed one of the ordinary drugs in apothecaries' shops (Egypt) . . . . As early as the twelfth century a physician, Al Mager, was in the habit of prescribing mummy for his patients. It was said to be good for bruises and wounds. After a time . . . the supply of genuine mummies ran out, and the traffickers had to manufacture them. They procured the bodies of all the criminals that were executed in gaols and of people who had died in the hospitals. They filled the bodies with bitumen and stuffed the limbs with the same substance; this done, they bound them tightly and exposed them to the sun. In this way they made them look like old mummies.

Further details relating to both the properties and uses of the bitumens are given by Eratosthenes.

The bituminous seepages along the Albanian coast were described by Aristotle, Strabo, and Pliny, and the oil found at Agrigentum, termed "Sicilian oil," a name which appears to have had considerable use, is described by Pliny (about 50 A.D.) and Dioscorides as being used in lamps for illumination.

The spectacular and truly extraordinary oil and gas phenomena in the Caspian region, notably at Baku, have aroused the wonder and awe of travelers of all time. The mysterious and eternal flames of gushing oil and gas and the streams of blazing oil flowing down the hillsides furnished an effective foundation for the religious cult of the fire worshipers or Parsees. The great temple near Baku has its parallel, also founded on gas seepages, in that near Kangra, in India, with interchanges of pilgrims, merchants, and mendicants.

Marco Polo, describing the phenomena at Baku, states[15] that people made great journeys to obtain oil at this locality. Later reporters of accepted accuracy of observation were Kaempfer,[16]

[13] E. A. W. Budge, 2d ed., pp. 174, 202, Cambridge Univ. Press, England, 1925.

[14] *Idem*, p. 212.

[15] Book 1, Ch. 3: Yule's ed. (1871), Vol. 1, p. 46.

[16] *Amoenit, Exot.* (1712), p. 224.

who visited Baku in 1684; Forster,[17] in 1784; and Hanway,[18] in 1754, who, describing the Baku fire temple, mentions the great quantities of oil then being gathered for commerce from that district and some of the islands in the Caspian Sea. Peter the Great, when taking over the Khanate of Baku, in 1723, directed that a master of refinery be sent to take possession of the white oils of the region. At the time of Hanway's visit to the region of the Caucasus he described the natives as cooking their food and burning their lime [as they do now] with gas from the springs and ground seepages in the vicinity of Baku. He says the oil from Sviatoi [Holy Island], near the Apscheron Peninsula in the Caspian Sea, was used as oil in lamps and for cooking and that the "white variety of naphtha" found in the Apscheron Peninsula was used for a "cordial (nonintoxicant) and a medicine, being taken internally for stone, disorders of the breast, venereal diseases, and sore heads; and externally for scorbutic pains, gout, cramps," etc.

Reporting a visit by him to the ruins of a shrine near Baku, I. C. White[19] noted that where an altar had been dismantled a hidden pipe was found to have been laid to conduct the natural gas from a fissure in the strata to its point of religious contemplation at the altar, "where its lambent flames had inspired the fire worshipers with a belief in the supernatural powers of the priests of Zoroaster." The oracular utterances of the priests may well have been inspired by the inhalation of the natural gas, the effects of which are reported to be comparable to those of nitrous oxide ("laughing gas").[20]

Oil in the neighborhood of Yenangyoung, a small tributary of the Irrawaddy in India, has been known for many centuries. Symes, who visited the region in 1765, reports:

> After passing various lands and villages, we got to Yenangyoung, or Earth-oil Creek, about 2 hours past noon. We were informed that the celebrated wells of petroleum which supply the whole empire and many parts of India with that useful product were 5 miles to the east of this place. The mouth of the creek was crowded with large boats waiting to receive a lading of oil, and immense pyramids of earthen jars were raised in and around the village, disposed in the same manner as shot and shell are piled in an arsenal. This is inhabited only by potters, who carry on an extensive manufactory and find full employment. The smell of the oil is extremely offensive. We saw several thousand jars filled with it ranged along the bank; some of these were con-

[17] Second journey (1784), p. 24.

[18] Jonas Hanway, *Historical Account of the British Trade over the Caspian Sea*, Vol. 1 (1754), pp. 263, 381.

[19] I. C. White, *Bull. Geol. Soc. America*, Vol. 32 (1921), p. 172.

[20] S. F. Peckham, *op. cit.*, p. 252.

tinually breaking, and the contents, mingling with the sand, formed a very filthy consistence.

Further information regarding India, including the development, method of operation, and production of the oil wells at Rangoon, was communicated to the British Government in 1826 by Sir John Crawfurd.[21]

How long oil and natural gas have been known and utilized in China and Japan cannot now be ascertained. In China natural gas was used both for lighting and heating, centuries before the Christian era. The "fire" wells in Szechwan, dug 1,500 to 2,000 feet deep, found brine, oil, and gas. The gas was piped to sheds for the evaporation of the brine. The use of oil in Japan is mentioned in literature as old as 615 A.D. Refining of oil was attempted as long ago as 1613, but it did not reach a commercial basis until 250 years later.

SPANISH AMERICA

Petroleum must have aroused the interest of the aborigines of the Americas centuries, probably millenniums, before the coming of Christopher Columbus. Father Joseph de Acosta, writing some time prior to 1604, says:

> At the point of Cape St. Helen there is a spring or fountain of pitch, which at Peru they called "copey." The mariners use this copey to pitch their ropes and tackling.[22]

The pitch lake on the island of Trinidad, near the mouth of the Orinoco River, was described by Nugent,[23] who in 1811 published an account of the region on his return to England.

Some of the beautiful mosaics made by the Toltecs, who preceded the Aztec race in Mexico, are delicately set in bitumen.[24]

2. OIL IN THE UNITED STATES BEFORE 1800

In California, where seepages of asphalt and highly viscous oils are comparatively abundant, it was found in excavating a shell mound at Emeryville that asphalt was used for sticking beads to various articles; for covering wrappings, such as the cords of charm stones; and possibly for purposes of decorative designs, apparently for esthetic more than practical purposes. It was used throughout the mound

[21] Journal of an embassy to the Court of Ava, 1834.

[22] Acosta, English translation by Edward Grimston, 1604; printed for the Hakluyt Society, Vol. 60 (1880), p. 155.

[23] Nicholas Nugent, *Geol. Soc. London Trans.*, 1st ser., Vol. 1 (1811), p. 63.

[24] M. H. Saville, *Turquois Mosaic Art in Ancient Mexico*, p. 29, Mus. Am. Indian, Heye Foundation, New York, 1922.

history in an art that to the archeologist suggests "a comparatively developed people."[25] The age of the mound, which is on the eastern shore of San Francisco Bay, is estimated at about 1,000 years.

The Canalinos made rather wide use of asphaltum, which they kept conveniently at hand in kneaded cakes. They used the hydrocarbon as an adhesive substance. Baskets were lined with asphaltum by placing some lumps of asphaltum in them and later a handful of hot pebbles, and when the pitch became fluid on account of the heat of the pebbles, the baskets were turned round and round until each part of the interior was uniformly covered, the weight of the revolving stones serving to press the liquid into the interstices of the weave.[26]

In the Lake Tulare region asphaltum was not only used for cementing baskets, but it also was placed over the eyes of the dead in burial. Clamshell beads were ornamented by incisions filled with the black substance.

Among the celebrated oil springs on Oil Creek, in Venango County, Pa., there are numerous pits which have sometimes been regarded as prehistoric, as the mounds of excavated dirt thrown out of the pits were covered by forest, perhaps 200 years old, when they were examined a century and a quarter ago. However, the reported discovery that some of the mounds were cribbed with logs and that old hatchets of French make were found near by makes it probable that the pits, obviously dug to obtain larger amounts of the oil, do not date back earlier than French explorations into northwestern Pennsylvania. It was in one of these old pits that the Drake well was sunk in 1859.

The earliest mention in modern literature of the presence of petroleum in the Appalachian region has long been supposed to be a letter written by a Franciscan missionary, Joseph de la Roche d'Allion, describing the well-known oil springs near Cuba, N.Y. This letter, published in Sagard's Histoire du Canada in 1632, indicates that the missionary crossed the Niagara River into what is now New York State and visited the oil springs as early at least as 1632. The account which has been much cited, is, however, condemned by E. B. Swanson,[27] an archeologist, who states, as a result of his researches, that this early traveler did not cross the Niagara River and did not visit the spring.

[25] W. E. Schenck, "The Emeryville Shell Mound," *California Univ. Pubs. in Archaeology and Ethnology*, Vol. 23, No. 3, (1926), p. 212.

[26] D. B. Rogers, *Prehistoric Man of the Santa Barbara Coast*, pp. 396, 398, Santa Barbara Mus. Nat. History, 1929.

[27] Quoted in Ralph Arnold and W. J. Kemnitzer, *Petroleum in the United States and its Possessions*, 1932.

In 1646 Charlevoix[28] writes:

> Approaching the country of the ancient Eries, there is a thick oily stagnant water which takes fire like brandy. [He probably refers to the well-known oil spring near Cuba, N.Y. It was from this spring that oil gathered by a Seneca chief who lived at Caniadeg (near Cuba), was sent in 1767 to Sir William Johnson, with the information that it was taken off the surface of a small lake near Caiadeon Castle.] The Indians have great faith in it for performing all manner of cures.

Peter Kalm published a book of travels in which the oil springs on Oil Creek were correctly located. An English translation of his narrative was published in London in 1772. Further description of the springs is found in the first volume of the *Massachusetts Magazine*, which states:

> In the northern part of Pennsylvania is a creek called "Oil Creek," which empties into the Allegheny River. It issues from a spring, on which floats an oil similar to that called "Barbadoes tar" and from which one may gather several gallons in a day. The troops sent to guard the western posts halted at this spring, collected some of the oil, and bathed their joints with it. This gave them great relief from the rheumatism with which they were afflicted. The water, of which the troops drank freely, operated as a gentle purge.

A cordial and rather wide-spread reception was given by the white settlers to this remedy, which was used by natives as a liniment applied for rheumatism, bruises, toothache, headache, and burns. The white man later made experimental medicinal applications both of crude oil and of natural gas, the oil having been tried and for a time regarded as curative for pulmonary tuberculosis and chronic bronchitis. The internal use of crude oil appears not to have been wholly satisfactory, though it is still sometimes drunk, often in bravado, by the driller, besides being used for the restoration of hair. The use of natural gas as an anesthetic, with results similar in some respects to those obtained by nitrous oxide, though notably lasting was not wholly satisfactory on account of the unfavorable heart reaction and the danger of suffocation.

As pioneer settlements spread to the west of the Appalachian Valley region, oil springs and asphalt seepages, often associated with salt licks, came to the attention of the white man in western New York, western Pennsylvania, eastern and southeastern Ohio, northern and central West Virginia, eastern Kentucky, eastern Tennessee, and northern Alabama.

In the early days, however, interest in the brine springs, or "salt licks," was far greater than in the frequently accompanying oil. In

[28] *Histoire et description générale de la Nouvelle France*, 1646.

fact, as will be noted later, the increase in the escaping oil, caused by sinking pits and the later drilling of wells to obtain larger and stronger supplies of brine, was regarded as a misfortune, many wells being abandoned in most of the above-mentioned states on account of the too copious issue of oil.

3. SALT INDUSTRY (1800–50) PREPARES WAY FOR OIL PRODUCTION

During the first quarter of the last century, except for the analytical and experimental researches on the oils, asphalts, and cannels carried on in Europe and to a less extent in America, progress toward the establishment of a future great American industry in petroleum, though effective, was principally accomplished indirectly and in two ways—first, through the discoveries of new oil seeps and larger oil supplies incident to the development of the salt industry, to meet the growing needs of the expanding Nation; and second, and probably of far greater importance, through the development of the fundamental features of construction of the modern standard cable drill rig. This epoch-marking step in petroleum history has not received the attention it deserves. It was brought about in 1806–8, over 50 years before the memorable well was drilled by Drake in Pennsylvania. The occasion was the drilling of a salt well at the "Great Buffalo Lick," a "saline" on the Kanawha River above Charleston, W.Va. The interest and importance of the event justify the repetition in part of the account prepared by Prof. M. F. Maury for the West Virginia Centennial Board.

It was not until 1806 that the brothers David and Joseph Ruffner set to work to ascertain the source of the salt water, to procure, if possible, a larger supply and of better quality, and to prepare to manufacture salt on a scale commensurate with the growing wants of the country.

The Salt Lick, or "the Great Buffalo Lick," as it was called, was just at the river's edge, 12 or 14 rods in extent, on the north side, a few hundred yards above the mouth of Campbells Creek, and just in front of what is now known as the "Thoroughfare Gap," through which, from the north, as well as up and down the river, the buffalo, elk, and other ruminating animals made their way in vast numbers to the lick. . . .

In order to reach, if possible, the bottom of the mire and the oozy quicksand through which the salt water flowed they [the Ruffner brothers] provided a straight, well-formed, hollow sycamore tree, with 4 feet internal diameter, sawed off square at each end. This is technically called a "gum." This gum was set upright on the spot selected for sinking, the large end down, and held in its perpendicular position by props or braces on the four sides. A platform, upon which two men could stand, was fixed about the top; then a swape was erected, having its fulcrum in a forked post set in the ground close by. A large bucket, made from half of a whisky barrel, was attached to the end of the swape by a rope, and a rope was attached to the end of the pole,

to pull down on, to raise the bucket. With one man inside the gum, armed with pick, shovel, and crowbar, two men on the platform on top to empty and return the bucket, and three or four to work the swape, the crew and outfit were complete.

After many unexpected difficulties and delays the gum at last reached what seemed to be rock bottom at 13 feet. Upon cutting it with picks and crowbars, however, it proved to be but a shale or crust about 6 inches thick of conglomerated sand, gravel, and iron. Upon breaking through this crust the water flowed up into the gum more freely than ever, but with less salt.

Discouraged at this result, the Ruffner brothers determined to abandon this gum and sink a well out in the bottom, about 100 yards from the river. This was done, encountering, as before, many difficulties and delays. When they had gotten through 45 feet of alluvial deposit they came to the same bed of sand and gravel upon which they had started at the river. To penetrate this they made a 3½-inch tube of a 20-foot oak log by boring through it with a long-shanked auger. This tube, sharpened and shod with iron at the bottom, was driven down, pile-driver fashion, through the sand to the solid rock. Through this tube they then let down a glass vial with a string, to catch the salt water for testing.

They were again doomed to disappointment. The water, though slightly brackish, was less salt than that at the river. They now decided to return to the gum at the river, and, if possible, put it down to the bedrock. This they finally succeeded in doing, finding the rock at 16 to 17 feet from the surface.

As the bottom of the gum was square and the surface of the rock uneven, the rush of outside water in the gum was very troublesome. By dint of cutting and trimming from one side and the other, however, they were at last gotten nearly to a joint, after which they resorted to thin wedges, which were driven here and there as they would "do the most good."

By this means the gum was gotten sufficiently tight to be so bailed out as to determine whether the salt water came up through the rock. This turned out to be the case. The quantity welling up through the rock was extremely small, but the strength was greater than any yet gotten, and this was encouraging. They were anxious to follow it down, but how? They could not blast a hole down there under water; but this idea occurred to them: They knew that rock blasters drilled their powder holes 2 or 3 feet deep, and they concluded they could, with a longer and larger drill, bore a correspondingly deeper and larger hole. They fixed a long iron drill, with a 2½-inch chisel bit of steel, and attached the upper end to a spring pole with a rope. In this way the boring went on slowly and tediously, till on the 1st of November 1807, at 17 feet in the rock, a cavity or fissure was struck, which gave an increased flow of stronger brine. This gave new encouragement to bore still further; and so, by welding increasing length of shaft to the drill from time to time the hole was carried down to 28 feet, where a still larger and stronger supply of salt water was gotten.

Having now sufficient salt water to justify it, they decided and commenced to build a salt furnace, but, while building, continued the boring, and on the 15th of January, 1808, at 40 feet in the rock and 58 feet from the top of the gum, were rewarded by an ample flow of strong brine for their furnace, and ceased boring.

Now was presented another difficulty: How to get the stronger brine

from the bottom of the well, undiluted by the weaker brines and fresh water from above. There was no precedent here; they had to invent, contrive, and construct anew. A metal tube would naturally suggest itself to them; but there were neither metal tubes, nor sheet metal, nor metal workers, save a home-made blacksmith, in all this region, and to bore a wooden tube 40 feet long, and small enough in external diameter to go in the 2½-inch hole, was impracticable. What they did do was to whittle out of two long strips of wood two long half tubes of the proper size, and fitting the edges carefully together, wrap the whole from end to end with small twine. This, with a bag of wrapping near the lower end, to fit as nearly as practicable, watertight in the 2½-inch hole, was cautiously pressed down to its place, and found to answer the purpose perfectly, the brine flowed up freely through the tube into the gum which was now provided with a watertight floor or bottom to hold it, and from which it was raised by the simple swape and bucket.

Thus was bored and tubed, rigged and worked, the first rock-bored salt well west of the Alleghanies, if not in the United States. The wonder is not that it required 18 months or more to prepare, bore, and complete this well for use, but rather that it was accomplished at all under the circumstances. In these times, when such a work can be accomplished in as many days as it then required months, it is difficult to appreciate the difficulties, doubts, delays, and general troubles that then beset them. Without preliminary study, previous experiences, or training, without precedents in what they undertook, in a newly settled country, without steam power, machine shops, skilled mechanics, suitable tools or materials, failure rather than success might reasonably have been predicted.

In the same connection and to complete the picture of the device now so familiar in every oil field of the world, further extracts from Maury which refer to the invention later of two additional parts of the driller's equipment are quoted.

Other important improvements were gradually made in the manner of boring, tubing, and pumping wells, etc. The first progress made in tubing after Ruffner's compound wood-and-wrapping-twine tube, was made by a tinner who had located in Charleston. . . . He made tin tubes in convenient lengths and soldered them together as they were put down the well. The refinement of screw joints had not yet come, but followed shortly after, in connection with copper pipes, which soon took the place of tin, and these are recently giving place to iron.

In the manner of bagging the wells—that is, in forming a watertight joint around the tube to shut off the weaker waters above from the stronger below—a simple arrangement, called a "seed bag," was fallen upon, which proved very effective and which has survived to this day and has been adopted wherever deep boring is done as one of the standard appliances for the purpose for which it is used. This seed bag is made of buckskin or soft calfskin, sewed up like the sleeve of a coat or leg of a stocking, made 12 to 15 inches long, about the size of the well hole, and open at both ends; this is slipped over the tube and one end securely wrapped over knots placed on the tube to prevent slipping. Some 6 or 8 inches of the bag is then filled with flaxseed, either alone or mixed with powdered gum tragacanth; the other end of the bag

is then wrapped like the first, and the tube is ready for the well. When to their place—and they are put down any depth to hundreds of feet—the seed and gum soon swell from the water they absorb, till a close fit and watertight joint are made. . . .

In 1831 William Morris, or "Billy" Morris, as he was familiarly called, a very ingenious and successful practical well borer, invented a simple tool which has done more to render deep boring practicable, simple, and cheap than anything else since the introduction of steam.

This tool has always been called here "slips," but in the oil regions they have given it the name of "jars." It is a long double link, with jaws that fit closely but slide loosely up and down. They are made of the best steel, are about 30 inches long, and fitted, top and bottom, with pin and socket joint, respectively. For use they are interposed between the heavy iron sinker, with its cutting chisel bit below, and the line of auger poles above. Its object is to let the heavy sinker and bit have a clear, quick, cutting fall, unobstructed and unincumbered by the slower motion of the long line of auger poles above. In the case of fast auger or other tools in the well, they are also used to give heavy jars upward or downward, or both, to loosen them. From this use the oil-well people have given them the name of "jars."

Billy Morris never patented his invention and never asked for nor made a dollar out of it; but as a public benefactor he deserves to rank with the inventors of the sewing machine, reaping machine, planing machine, printing cylinders, cotton gin, etc. This tool has been adopted into general use wherever deep boring is done, but outside of Kanawha few have heard of Billy Morris, or know where the "slips" or "jars" came from.

Nearly all the Kanawha salt wells have contained more or less petroleum, and some of the deepest wells a considerable flow. Many persons now think, trusting to their recollections, that some of the wells afforded as much as 25 to 50 barrels per day. . . .

At that time this oil not only had no value but was considered a great nuisance, and every effort was made to tube it out and get rid of it.

The successful boring of the Ruffner well in West Virginia not only opened a new era in the salt industry; it constituted a vast step in preparing the way for the petroleum commerce of America.

After the completion of the Ruffner well in 1808, the use of drill rigs, embodying the essential characters described above, very rapidly replaced hand digging throughout the salt-producing regions of the country, with great success. Wells along Duck Creek, in Ohio, were drilled to depths of 475 feet or more as early as 1814. The number of salt wells increased rapidly, with betterment in the quality of the brines used. Peckham remarks: "The valley of the Muskingum from Zanesville to Marietta soon became noted, and the valley of Duck Creek, since the center of the Washington County [Ohio] petroleum fields, was first famous for its salt wells." Boring supplanted digging in Jackson County, Ohio, where the "Old Scioto salt works" had been established as early as 1798. In boring for salt in the neighborhood of Tarentum, Pa., about 1810, small oil issues

were found to be such a hindrance to the successful operation of some of the wells (believed to have been drilled by the newly devised rig) that they were abandoned.

Undesired oil was found in annoying quantities in some of the salt wells bored along the Big Sandy River and its tributaries in Kentucky and in some of the explorations in northern Tennessee, where wells were sunk as early as 1820. Some of the wells in which the brine was pumped too steadily began to produce oil and were abandoned in disgust by the owners. One well, later known as the "Beatty well," drilled in 1818 or 1819 on the South Fork of the Cumberland River, in Wayne County, Ky., yielded such large amounts of oil that it was abandoned and apparently almost forgotten for more than 30 years. Oil was found also in many salt wells drilled in Barren and Cumberland Counties, Ky. The most widely known of the wells drilled in Kentucky during this early period of the last century was the celebrated American well bored on Little Rennox Creek, near Burkesville, in 1829. A contemporaneous record states that—

> A vein of pure oil was struck, from which it is almost incredible what quantities of the substance issued. The discharges were by floods at intervals of from 2 to 5 minutes, at each flow vomiting forth many barrels of pure oil. I witnessed myself, on a shaft that stood upright by the aperture in the rock from which it issued, marks of oil 25 or 30 feet perpendicularly above the rock. These floods continued for 3 or 4 weeks, when they subsided to a constant stream, affording many thousand gallons per day. This well is between a quarter and a half mile from the bank of the Cumberland River, on a small rill (creek), down which it runs to the Cumberland River. It was traced as far down the Cumberland as Gallatin, in Sumner County, Tenn., nearly 100 miles. For many miles it covered the whole surface of the river, and its marks are now found on the rocks on each bank. About 2 miles below the point on which it touched the river it was set on fire by a boy, and the effect was grand beyond description. . . .

Of this well C. L. S. Mathews, writing in 1876, states:

> When first struck, oil flowed from it at the rate of 1,000 barrels per day, and for many years—in fact, until the year 1860—it yielded a plentiful supply of oil. . . . Some years after this strike was made several individuals took charge of the well, saved the oil, and put up several hundred thousand bottles, which they sold all through this country and some parts of Europe as the "American Medicinal Oil, Burkesville, Kentucky."

In 1814 De Witt Clinton[29] wrote:

> There is a bituminous spring in Alleghany County whence the famous Seneca oil is obtained. . . . At Amaino, in Italy, the petroleum of a spring discovered within a few years is employed to light the cities. . . . It might be

[29] New York Lit. and Philos. Soc., May 4, 1814.

of considerable consequence to discover whether the petroleum of our spring might not be used for like beneficial purposes.

In 1821 natural gas was used for lighting houses in Fredonia, N.Y., and in 1828 petroleum was recommended for use in lamps to light the streets of Pittsburgh, Pa.[30]

Oil seeps in Wirt and Ritchie Counties, W.Va., were described by S. P. Hildreth in the *American Journal of Science* for February, 1826. The same writer, commenting on the occurrence of oil in the salt wells of the Big and Little Muskingum Rivers, remarks:

> Petroleum affords considerable profit and is beginning to be in demand for lamps and work shops and manufactories. It affords a clear, brisk light when burnt this way and will be a valuable article for lighting the street lamps in the future cities of Ohio.

From the records cited above it would appear that for several years after the invention of the drill rig, in 1808, the then very limited market for petroleum was so oversupplied that oil was thrown away and salt wells within 20 miles of Pittsburgh were abandoned when found to yield too much petroleum. However, if the statement of Mathews is accurate, the "American medicinal oil" from the American well enjoyed a relatively widespread market some years after it was drilled in 1829. This growth in the demand for petroleum is reflected in an article by Dr. S. P. Hildreth, of Marietta, published in the *American Journal of Science* in 1833. He says:

> Since the first settlement of the regions west of the Appalachian Range the hunters and pioneers have been acquainted with this oil. Rising in a hidden and mysterious manner from the bowels of the earth, it soon arrested their attention and acquired great value in the eyes of those simple sons of the forest. Like some miraculous gift from heaven, it was thought to be a sovereign remedy for nearly all the diseases common to those primeval days, and from its success in rheumatism, burns, coughs, sprains, etc., was justly entitled to all its celebrity. It acquired its name of "Seneca oil," that by which it is generally known, from having first been found in the vicinity of Seneca Lake, N.Y. From its being found in limited quantities and its great and extensive demand, a small vial of it would sell for 40 or 50 cents. It is at this time in general use among the inhabitants of the country for saddle bruises and that complaint called the "scratches" in horses. It seems to be peculiarly adapted to the flesh of horses and cures many of their ailments with wonderful certainty and celerity. Flies and other insects have a natural antipathy to its effluvia, and it is used with much effect in preventing the deposit of eggs by the "blowing fly" in the wounds of domestic animals during the summer months. In neighborhoods where it is abundant it is burned in lamps in place of spermaceti oil, affording a brilliant light, but filling the room with its own peculiar odor. By filtering it through charcoal much of this empyreumatic

[30] J. F. Carll, *Pennsylvania 2d Geol. Survey Ann. Rept. for 1886*, Pt. 2 (1887), p. 593.

smell is destroyed and the oil greatly improved in quality and appearance. It is also well adapted to prevent friction in machinery, for, being free of gluten, so common to animal and vegetable oils, it preserves the parts to which it is applied for a long time in free motion; where a heavy vertical shaft runs in a socket, it is preferable to all or any other articles. This oil rises in greater or less abundance in most of the salt wells of the Kanawha and, collecting as it rises, in the head of the water, is removed from time to time with a ladle. . . .

The oil from this well is discharged periodically at intervals of from 2 to 4 days and from 3 to 6 hours' duration at each period. Great quantities of gas accompany the discharges of oil, which for the first few years amounted to from 30 to 60 gallons at each eruption. The discharges at this time are less frequent and diminished in quantity, affording only about a barrel per week, which is worth at the well from 50 to 75 cents a gallon.

The source, the name "Seneca oil," and the contemporaneous value of petroleum in the region are considered also in an interesting article by Benjamin Silliman, Sr., published the same year in the same journal, in which he describes the then very famous oil spring of the Seneca Indians near Cuba, N.Y. He says:

The oil spring, or fountain, rises in the midst of a marshy ground; it is a muddy and dirty pool about 18 feet in diameter, and is nearly circular in form. There is no outlet above ground, no stream flowing from it, and it is, of course, a stagnant water, with no other circulation than that which springs from changes of temperature and from the gas and petroleum which are constantly rising through the pool.

They collect the petroleum by skimming it, like cream from a milk pan. For this purpose they use a broad, flat board, made thin at one edge like a knife; it is moved flat upon and just under the surface of the water, and is soon covered by a coating of the petroleum, which is so thick and adhesive that it does not fall off but is removed by scraping the instrument upon the lip of a cup. It has then a very foul appearance, like very dirty tar or molasses, but it is purified by heating and straining it while hot through flannel or other woolen stuff. It is used by the people of the vicinity for sprains and rheumatism and for sores on their horses, it being in both cases rubbed upon the part. It is not monopolized by anyone but is carried away freely by all who care to collect it, and for this purpose the spring is frequently visited. I could not ascertain how much is annually obtained; the quantity must be considerable. It is said to rise more abundantly in hot weather than in cold.

I cannot learn that any considerable part of the large quantities of petroleum used in the Eastern States under the name of "Seneca oil" comes from the spring now described. I am assured that its source is about 100 miles from Pittsburgh, on Oil Creek, which empties into the Alleghany River in the township and county of Venango. It exists there in great abundance and rises in purity to the surface of the water; by dams, enclosing certain parts of the river or creek, it is prevented from flowing away, and it is absorbed by the blankets, from which it is wrung.

Inasmuch as little seems to be known of an oil spring near Seneca Lake, in New York, while on the other hand the very well known oil

springs at Cuba, N.Y., and Oil Creek, Pa., were not only utilized by the Indians but were both located in the territory of the Seneca Indians, it appears to the writer very probable that the early name "Seneca oil" was taken from the tribe of Indians who were the distributors of petroleum from these sources long before the coming of the white man, rather than from a spring near Seneca Lake, which could hardly have furnished more than an insignificant amount, insufficient for the indicated trade consumption. Although from Professor Silliman's statement it appears that the spring at Cuba was "not monopolized" in 1834, we may nevertheless conclude that the oil from the springs both at Cuba and at Oil Creek was saved for use in lamps, as well as for medical purposes. The oil springs on the Little Kanawha were described by Hildreth in 1836.

In 1845 petroleum from a salt well at Tarentum, Pa., was mixed with sperm oil to lubricate the spindles of the Hope cotton factory, in Pittsburgh, with reported great economy as well as success, the cost of the mixture being but 70 cents a gallon, while the price of sperm oil was $1.30.

In the period 1850–55 the oil from Tarentum was refined in Pittsburgh and sold for lamp use as "carbon oil," for which the market became sufficient to absorb the available output.[31]

Peckham points out that the period 1820 to 1830 was one of great activity in the investigation of the occurrence and character of the bitumens in different parts of the world. Paraffin obtained by the destructive distillation of wood was discovered by Reichenbach in 1824 and analyzed by Gay-Lussac in 1825. Broussingault's studies of the bitumens found at Pechelbronn, in Alsace, did much to stimulate both analytical and experimental researches with reference to the properties and possible utilization in new ways of petroleum and its derivatives.

4. OILS FROM COALS AND SHALES FOR LIGHT AND LUBRICATION 1850–59

The outstanding feature of the second quarter of the last century was the development of the shale-oil industry in western Europe and eastern America. This interesting phase in industrial history was the product of research and experiments due to progress in the development of the lamp; progress in the methods of separating or refining shale oils, notably the recovery of paraffin and kerosene; and the adaptation of these methods to petroleum and the resultant great advance in the price of crude oil, which, according to Peckham,

[31] J. F. Carll, *op. cit.*, p. 495.

had by 1859, the date of the Drake well, attained values of $40 to $50 a barrel.

The driving cause throughout the great development of the shale-oil industry, which took place between 1830 and 1860, but mainly in the last 10 years of that period, was the necessity for a cheaper substitute to replace the dwindling supplies of sperm and whale oils. Experimental and analytical investigations had long been in progress, especially in Great Britain and France, and testing and even limited utilization of these shales for the production of oils began early in this period. In Great Britain distillation of coals and shales dates as far back as 1694.

Paraffin had been obtained from bituminous shale in France in 1830 by Laurent, who in 1835 suggested working the Autun shale on a commercial scale, utilizing the process devised by Selligue. This was accomplished before 1845.[32]

In the same year (1830) in which Laurent's recovery of paraffin from shale was announced, Christison found paraffin in Rangoon oil and named it "petroline," but this term failed to displace the name "paraffin" given to the substance extracted from beechwood and analyzed by Reichenbach in 1824.

About 1847 James Young, who was familiar with the methods of whale-oil refining in Scotland, following the experimental methods of Christison, extracted paraffin from the oil in a petroleum seepage at Alfreton, in Derbyshire, and manufactured wax from it. However, finding the supply of oil inadequate, he turned to coal and shale distillation and in 1850 obtained a patent for a process for "treating bituminous coals in such a manner as to obtain therefrom an oil containing paraffin and from which I obtain paraffin." The Scotch industry was founded by him and his associates in 1851 at Bathgate, where it experienced a great expansion from a few hundred tons of Scotch boghead a year to a consumption of over 10,000 tons in 1860. Paraffin, which was in great demand for the manufacture of candles, was put on the market by Young at about half the cost of that produced by competing refineries.

By the time the Drake oil well was drilled there were over 130 plants in Great Britain and 64 plants in the United States, where from about 1845 testing and production of oil from fatty coals and bituminous shales had been in progress. Some at least of the American plants operated under the Young patent, which had been extended to America.

[32] H. B. Cronshaw, "Oil shales," *Imp. Inst. Monographs on Mineral Resources of the British Empire* (1921), p. 54.

Plants at Portland, Boston, and Brooklyn utilized the so-called Albert "coal," mined in New Brunswick. At New Bedford, Mass., the center of the whaling industry in America, Scotch boghead was imported for the manufacture of paraffin oils, in which some of the equipment as well as the experience left by the declining whale-oil industry were put to use. Other plants built for the distillation of cannel coals, some of which approached bogheads in composition, were developed in western Pennsylvania, the Kanawha region of West Virginia, and near the Ohio River in eastern Kentucky, where extensive deposits of cannel coal were available, and at Cloveport, in western Kentucky, where, in Breckenridge and other counties, richly bituminous cannels are found. Works were also located at Canfield and Newark, Ohio. The operations on the Alleghany River, known as the "Lucesco," were in 1859 the largest in America, with a daily capacity of 6,000 gallons of crude oil. Meanwhile, American importers of Scotch boghead ("torbanite") had been buying it at a cost of £4 to £5 a ton, delivered, and royalties of 2 pence a gallon were paid on the Young patents. Boghead of high grade is capable of yielding 130 to 140 gallons of oil to the ton—very pure boghead as much as 170 gallons. High-grade cannel yields 40 to 45 gallons to the ton. With rock oil worth $30 a barrel, as stated by I. C. White or $40, as quoted by Peckham, it is evident that a great shortage of petroleum was felt at this time in America as well as in western Europe.

The very rapid increase in the American petroleum output that followed the sinking of the Drake well, in 1859, soon lowered the prices of oil to the point where the industry founded upon the distillation of coal and oil shales in America was ruined, many of the refineries being adjusted or remodeled for the treatment of petroleum. Though the industry was crippled for a considerable period, it still survived in Great Britain until 1923, and in France to a later date, with the help of protective tariffs.

5. THE DRAKE WELL, 1859

It has been noted that the petroleum issuing from the salt wells at Tarentum, Pa., in 1810 was regarded as a great detriment, wells being abandoned for that reason. Even as late as 1845 oil from newly drilled salt wells in that vicinity was allowed to drain into a near-by canal. However, by 1850 some of the oil was bottled and sold by druggists, and a little later, about 1855, the oil was refined by methods used for the treatment of oil from coal, one of the products being used for cleansing wool. Meanwhile, according to Peckham, after about

1854 oil that had been gathered near Mill Creek, in Erie County, Pa., was sold in the drug trade at $1 a gallon.[33]

An oil spring in the same county, enlarged by digging in 1845, is said to have flowed until 1880 at least. "As good or better than crude oil from coal" was the judgment of Mr. Everett, a manufacturer of oil from cannel coal, to whom J. S. Newberry sent some petroleum from Mecca, Ohio.[34] Oil from coal thus served as a standard for the comparison of petroleum.

Meanwhile, advancing prices of rock oil and the growing knowledge of petroleum and its uses in the production of lamp oils (kerosene), paraffin, and lubricants were developing widespread interest in petroleum in America. With oil selling at $30 or $40 a barrel in 1855, it may be supposed that in portions of this country oil hunger was acute.

In 1857 favorable reports of tests of Oil Creek oils by Prof. Benjamin Silliman, Jr., of New Haven, and other New England investigators encouraged the formation of a company consisting mainly of New Haven capitalists, for leasing and exploration for oil on Watsons Flat, on Oil Creek, Pa., where oil seepages occurred. In fact, the first well drilled for oil was sunk in one of the long-forgotten pits.

E. L. Drake, superintendent of the property of the Seneca Oil Co., assembled the equipment[35] to drill a hole in 1858 and drove an iron pipe down 36 feet to bedrock. The work was delayed, however, until 1859, when his crew arrived in June and got the work under way by the middle of August. On Saturday, August 28, 1859, the drill had bored but 33 feet when it fell 6 inches into a crevice, making the total depth of the well 69½ feet. The next day, Sunday, the head

[33] Quoted prices, dating back to the early period, vary not only with the region, but with reference to the scale of the transaction. Some of them are multiples of the retail prices for small amounts, there having been perhaps no wholesale rate and no exchange of the commodity in bulk.

T. J. A. Freeman, "Petroleum—a Historical Sketch," *Am. Catholic Quart.*, Vol. 20 (1895), p. 404, quotes George H. Loskiel to the effect that in 1789 the Indians sold Seneca oil at the rate of 4 guineas a quart, equivalent to about $20 a quart or $80 a gallon; but that in 1800 the price was $16 a gallon.

Basing his values on New York and Pennsylvania sales, Freeman gives $42 ± per barrel of 42 gallons in 1843 and $29.40 per barrel in 1857.

[34] S. F. Peckham, *op. cit.*, p. 10.

[35] It is thought by many that the glamorous Drake well was based upon a new discovery of a method of deep drilling. This idea is incorrect, for, as noted on a previous page, the drilling of holes to a depth of 400 feet or more had been accomplished as early as 1814 by the rig developed in 1808 and later years and long employed in the brine fields. In this period a small derrick had replaced the "gum," the walking beam was substituted for the spring pole, iron casing had replaced wood, and the steam engine was used instead of man power. Consistent with the use of salt-well equipment and methods, we find that the drill crew at the Drake well was brought from one of the Kanawha salt-well districts.

driller, William Smith, on visiting the well found it nearly full of oil. Then began the era of racing for leases and wild speculation in oil properties, though the Drake well was but a 25-barrel well.

The production of oil by distillation of coals, mainly cannel coals, cannel bogheads, and bogheads, was abandoned soon afterward, and many companies became bankrupt, though, on the other hand, a good proportion of the refineries using oil from coal were adapted to the treatment of petroleum and were so operated for a long time. The name "coal oil," early applied to the "lamp oil" or kerosene made from coal distillates and later transferred to the corresponding product of petroleum, is a reminder often heard, especially in the Middle States and the Mississippi Valley, of a once important and suddenly extinguished industry in America.

6. SOME OUTSTANDING FEATURES OF OIL-FIELD DEVELOPMENT IN THE UNITED STATES, 1859–1934

1859–1900

The inspiration of the leaders of the Seneca Oil Co. to drill the Drake well lay in the discovery of more copious and more salty brines at the considerable depths reached by drilling in some of the salt fields.

As might be expected, the first wells that followed the Drake were drilled in near-by regions. Outside of Pennsylvania drilling followed the trails blazed by the salt industry and tested the many seepages of oil which had come to the attention of the early settlers, chiefly in New York, Ohio, West Virginia, Kentucky, and Tennessee. . . .

A short pipe line laid from the Miller farm to Pithole, Pa., late in 1865 is said to be the first in America. Other lines were laid not long afterward. A 6-inch line laid in 1876 from a gas well in Butler County to Sharpsburg, a distance of 17 miles, supplied all the requirements of an iron plant for smelting as well as for light and heat. A more ambitious though not more significant undertaking was the building of the tidewater pipe line to carry oil from the Bradford field to Williamsport, Pa., 100 miles distant, in 1879.

During this period important advances were also made in the geology of petroleum and the methods of its discovery. The "anticlinal theory" of the occurrence of oil, foreshadowed by William Logan and H. D. Rogers, was fully formulated by T. Sterry Hunt in 1861 and by E. B. Andrews at a closely following date. It seemed, however, to have won little or no credence by the oil companies. Oil fields were discovered by chance wildcatting, propinquity, topography, and other unscientific bases, in general totally without

regard for local geologic structure. In 1883, Dr. I. C. White,[36] then engaged in examining the geology in and about the West Virginia and southwestern Pennsylvania oil fields, revived or rediscovered the "anticlinal theory" and supported it with such power of example, as well as precept, as to gain the confidence of most geologists, though this was of little advantage to the industry, which in general continued to ignore geologic aid. The conversion of the industry to geology as an aid to prospecting began within the present century and was nearly coincident with the beginning of the present period of overproduction.

Another step of considerable importance in the later development of the American oil fields was the adoption of instrumental determinations of the altitudes of "key" rocks in areas under geologic investigation and the representation of anticlines, domes, and other features of geologic structure by structure contours.[37] In this method the plane table and alidade, the latter somewhat remodeled for light field use, replaced the aneroid barometer, formerly generally employed. Structure contouring is now almost universally used in oil-field mapping throughout the world.

For the transportation of oil, tank cars were used on the Baltimore & Ohio Railroad in 1866. Sailing ships with tank compartments soon followed, and steamships in 1879.

The development of the high-speed internal-combustion engine by Daimler in 1883 paved the way for the automobile devised by him in 1887 and the invention of the diesel engine, patented in 1895.

Gasoline rose from a waste product to supersede kerosene in scope and importance.

From a table prepared by Anna Coons[38] it is seen that the production of petroleum in the United States in 1859, amounting to 2,000 barrels, had an average value of about $16 a barrel, and that the production for 1860 was 500,000 barrels, worth $9.60 a barrel. As the yield rose the price declined, so that as early as 1861, when the production in the United States was 2,114,000 barrels, the oil was sold at an average price of 49 cents a barrel for the year, and before the end of that year, as already mentioned, oil in western Pennsyl-

[36] *Science*, June, 1883.

[37] This method, introduced in the United States by J. P. Lesley when mapping coal lands in the late fifties and first used to show oil-field structure by B. S. Lyman in a general report on the Punjab oil lands in 1870, was adopted by the U. S. Geological Survey, through whose mapping of many coal and oil fields, under the direction of M. R. Campbell, its merits were effectively brought to the attention of geologists, especially during the early years of the present century.

[38] D. T. Day, *Handbook of the Petroleum Industry*, Vol. 1, New York, 1922, p. 328.

vania sold as low as 5 cents a barrel. The mercurial career of petroleum dates from the beginning of the industry.

1901–34

The early years of the twentieth century were marked by great advances in oil-field development,[39] in petroleum technology, in the application of petroleum in the arts, warfare, and commerce, and in geologic methods of discovering oil fields.

The first successful drilling of a salt dome at Spindletop, Tex., 1902, by Capt. A. F. Lucas, accomplished with spectacular results that attained world-wide publicity, opened the way to the development of the entire salt-dome belt of the Gulf Coastal Plain west of the Mississippi River. Salt-dome production in Louisiana followed in 1902, but production from other sources in northern Louisiana, where numerous seepages on the Sabine and Calcasieu Rivers were known in 1839,[40] was not achieved until 1906. . . .

A notable step in the oil industry was the development of methods for the production of casing-head gasoline, established in the Mid-Continent field in 1911; and important advances in refinery practice were the cracking of heavy oils and residues for the production of lighter and more valuable commodities, and the manufacture of tetra-ethyl lead and bromine-antidetonation gasolines. Then began the period of the gasoline-driven automobile, motor truck, tractor, and tank; of oil- or gasoline-driven motors for ships, locomotives, power plants, and railway cars. Gasoline made practicable the airplane and fast boats, and fuel oil promises to make them economical in operation. Gasoline is no longer a waste product.

Flooding in the Bradford field of Pennsylvania, the effect of which was accidentally discovered many years before, was legalized in 1920, when growing attention was being given to the problem of the recovery of more of the oil remaining in the sands when pumping was no longer profitable. Water drive was in general superseded, with far greater success, by gas drive, air drive, and conservation of the original gas pressure in the wells.

Through the experiences of its allies, as well as its enemies, as developed in the course of the World War, and especially through the testimonies of the leaders in the military and naval efforts, the United States was forcefully reminded of the fundamental importance of

[39] Accounts of the discoveries of new fields and production curves will be found in the discussions of the individual states, as published in 1934 on pp. 910–1086, Part 2 of the Hearings on House Resolution 441 before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Congress (Recess).

[40] W. M. Carpenter, *Am. Jour. Sci.*, Vol. 35 (1839), p. 345.

adequate petroleum reserves and their successful utilization in war as well as in industry, commerce, manufacture, the home, and other phases of civilization. The efforts of European nations to procure oil territory in different lands in as large areas as possible for the protection of their future brought somewhat abruptly to the delinquent attention of America the question as to the status of this country when the exhaustion of our wastefully exploited oil resources should cause acute shortage.

The discussions that ensued showed the need for an appraisal, necessarily rough and vague as it might be, of the petroleum resources of the United States with a forecast of their prospective duration. The first of the estimates[41] prepared during the war period by geologists of the United States Geological Survey[42] in response to a Senate resolution of January 5, 1916, was necessarily compiled in haste with none too searching consideration of the so-called "proved areas" and with rough estimates covering all other areas, based on the available geologic information as to the conditions of occurrence of oil and as to the existence and extent of areas appearing to meet the supposed requirements, but not yet tested. These "estimates" of 7,704,000,000 barrels "remaining in the ground at the end of 1915" and "recoverable by present methods" were inevitably highly speculative and little better than carefully prepared guesses.

In the spring of 1917 another estimate[43] in the formulation of which "the production records and the possible oil regions were closely considered, with marked conservatism, by the same geologists" placed the amount available at 6,182,000,000 barrels, and in January, 1919, these figures were raised to 6,740,000,000 barrels.

This was followed in 1921 by a more thorough canvass, made by the United States Geological Survey with the coöperation of the American Association of Petroleum Geologists through a specially appointed committee of geologists associated with the producing companies in the oil-yielding States.[44] This inventory, published early in 1922, amounted to 9,150,000,000 barrels available in the ground at the beginning of that year. In this appraisal the attention of the non-Government geologists was especially engaged with the unmined oil and future production or reserves of the producing fields; for the non-

[41] Earlier estimates had been made in 1908 by David T. Day, (*U. S. Geol. Survey Bull. 394*, p. 35—10,000,000,000 to 24,500,000,000, barrels "estimated total yield") and in 1915 by Ralph Arnold (*Econ. Geology*, Vol. 10, p. 695—5,763,000,000 barrels "available in ground at the end of 1914").

[42] 64th Cong., 1st sess., *S. Doc. 310*, 1916.

[43] Communicated to the press by the Secretary of the Interior.

[44] "The Oil Supply of the United States," *Dept. Interior Press Notice, 1922.*

producing states and regions the estimates were largely based upon the knowledge and views of the Federal members of the joint committee. Anomalously, as basic information increased the estimates were increased, although the progress of exhaustion of the reserves was shown by mounting annual production.

Estimates published subsequently by other organizations include those of (1) the "Committee of Eleven" of the American Petroleum Institute,[45] formulated in special terms, as explained below; (2) the Federal Oil Conservation Board in 1926 (4,500,000,000 barrels "available from flowing and pumping wells from present producing and proven fields");[46] (3) the Federal Oil Conservation Board in 1932 (10,000,000,000 barrels from "known reserves");[47] (4) Arnold and Kemnitzer in 1931 (39,092,000,000 barrels, "estimated ultimate production" as of January 1929);[48] and (5) Garfias in 1933 (12,000,000,000 barrels, "proven oil reserves—the oil that yet remains underground in the producing fields—and their logical extensions").[49]

The estimate by the experts of the American Petroleum Institute differed in scope and terms from all the others. It allocated 5,300,000,000 barrels to proved areas and "present methods of flowing and pumping." A second item of 26,000,000,000 barrels included oil that will be left in the ground in the same areas when flowing and pumping cease, "a considerable portion of which can be recovered through known methods." These methods include mining the oil sand and "leaching or retorting it," which is nearly equivalent to complete extraction of the oil content of the sand. Finally, the Committee of Eleven concluded that the United States contains 1,100,000,000 acres of land underlain by "geological formations favorable for oil." The yield of this territory, which embraces roughly almost half of the country, was not estimated.

How widely the earlier estimates, especially those issued by the Government during the war period, fell short of the truth may be guessed by consulting the production records since the estimates were published. It is a significant fact that the production in the United States exceeded 1,000,000,000 barrels in 1929, the peak year thus far.

Some of the reasons for the gross deficiencies in the estimates

[45] *American Petroleum Supply and Demand*, Am. Petroleum Inst. (1925), pp. 3, 7–13.

[46] *Federal Oil Cons. Board Rept. 1* (1926), p. 8.

[47] *Federal Oil Cons. Board Rept. 5* (1932), p. 7.

[48] Ralph Arnold and W. J. Kemnitzer, *Petroleum in the United States and Possessions* (1931), p. 51.

[49] V. R. Garfias, *Am. Inst. Min. Met. Eng. Trans.*, Vol. 103 (1933), p. 353.

published by the Government are obvious, though as incidents of history they are overlooked and to a great extent forgotten. The major reasons are the state of geologic knowledge at the time as to the conditions controlling the occurrence of oil; the changing conditions of oil recovery; and the conservatism of the estimators, who had only the production records and results of exploration available at the time. Each of the estimates included only the oil recoverable within a depth of 5,000 feet by the methods of recovery then practiced. It was not then thought that oil would probably be found and recovered at greater depths. Since those estimates were made, however, a few wells have been drilled to depths of more than 10,000 feet, or nearly 2 miles, and much oil is now found in the Gulf Coastal Plain in sands more than 5,000 feet deep.[50]

Since the World War numerous wells in different parts of the country have been driven far deeper than 1 mile. Three wells near Ligonier, Pa., drilled in 1923 and 1925, in a zone of too great carbonization to permit reasonable hope of finding oil in paying amounts, were sunk to depths of 6,822, 6,989, and 7,756 feet. Recently two wells in Caddo County, Okla., reached depths of 11,230 feet in the Binger dome and 10,079½ feet in the Cement pool. In the Rincon Field, Ventura County, Calif., a well was drilled in 1931 to a depth of 10,040 feet; a well in the Santa Maria field was abandoned in 1932 at a depth of 10,296 feet; a well in the North Kettleman Hills sunk to a depth of 10,994 feet, is now in process of redrilling; and the Berry No. 1 well, in the Belridge Field, Kern County, stopped in June, 1934, at a depth of 11,377 feet.[51] This last-mentioned well, the deepest in the world, is now (August, 1934) "fishing."[52] The account of its drilling records a remarkable achievement in oil-field engineering.

A second factor that will increase production beyond the estimated limits is the introduction of more efficient methods of recovery. When the last estimate was made a recovery of 50 percent of the oil in the sand was regarded as exceptionally high and was obtained only in certain regions or under extremely favorable circumstances, the recovery being generally only 12½ to 30 percent.[53] The American

[50] A well was drilled on Peters Creek, near West Elizabeth, Pa., to a depth of 5,380 feet prior to 1887; the Derrick City well, near Bradford, Pa., was driven to 5,760 feet before 1918; and the Gerry well, near McDonald, Pa., reached a depth of 7,248 feet in 1914.

[51] *Oil and Gas Jour.*, June 28, 1934.

[52] *Oil and Gas Jour.*, Aug. 30, 1934.

[53] J. O. Lewis, "Methods for Increasing the Recovery from Oil Sands," *U. S. Bur. Mines. Bull. 148* (1917). *American Petroleum Supply and Demand*, Am. Petroleum Inst. (1925), p. 97.

Petroleum Institute committee seems to have estimated[54] the average recovery for the entire country at 25 percent on the basis of oil extraction in 1925.

Water drive, the effect of which in forcing the oil in larger amounts from the sand into the wells is claimed to have doubled the production in the Bradford region, was used very little elsewhere when the estimate of 1922 was made. Since that time better spacing and timing of drilling, gas drive or gas lift and air pressure, and conservation of gas pressure have been very successfully applied with resulting recoveries of notably larger percentages of the oil from the sand and with greatly extended life of many of the fields. Some abandoned fields have been reopened by the new methods, with consequent rejuvenated production which is still in progress.

Obviously the estimates prepared during the war period have been in process of becoming obsolete almost from the day they were announced. They were destined to be invalidated, with progressively apparent disparity, on account of the changing basis of recovery. As a matter of fact, so complex and gradual are the changes that close determination of the extent to which these estimates differ from ultimate realization can never be made. It is to be added that the estimates of the reserves in "proved" territory, though prepared with much care on the basis of the geologic and production information available at the time, were avowedly conservative, as was to be expected and justified. However, although production has increased enormously beyond what was predicted as its coming peak, and the undeveloped reserves are, in general, also going beyond the predictions, it should be stated that oil in commercial quantity has not been found in any state that was not regarded in 1922 as offering promise of oil reserves, and on the other hand, all the subsequently discovered fields fall within the limits of the "favorable" territory and for by far the most part in the "probable" column.

The aims of the wartime estimates of the country's petroleum reserves were educative. The warning forecasts were designed to shatter the complacent obsession that the United States "has all the oil it will ever need," entertained by the public in general and to a deplorable extent by the Congress and administrative officers of the Government. Even the oil companies were seemingly ruled by the conviction that no one now living would ever see a shortage of oil caused by the exhaustion of our oil fields.

The estimates were widely printed, with great ultimate benefit to the public and the Government and with both good and bad effects

[54] *Op. cit.*, p. 101.

on the industry. Both the Congress and the heads of the Federal departments were awakened to the need for guaranteeing oil supplies adequate to meet the rapidly expanding military and naval as well as civil requirements of the United States and to postpone the day when the peak of production would have been passed and the long strain of growing lack of oil would become a reality, though the needs and uses for oil in all aspects of civilization might be still increasing. It was more fully recognized not only that this country had been prodigally wasteful of its petroleum and natural gas but that it had with lavish hand divided its oil with the rest of the world and freely permitted the nationals of foreign countries, countries that closed their doors to American oil companies, to acquire holdings of our oil territory. The United States had been eating its cake as rapidly as possible, without thought as to the size of the pan in which it had been baked. It was also recognized as probable, if not equally obvious, that the country whose oil is first exhausted, whether by waste, use, or gifts, may in consequence the sooner become dependent on, and even at the mercy of, nationals of other countries for what in this age has become one of the great necessities of life.

The diplomatic procedure of other nations, even our allies, in acquiring foreign petroleum reserves to the secretly arranged exclusion of our nationals was not without effect on the companies as well as on the administration. The lessons of the World War may have been as effective as the oil estimates in stimulating the prompt efforts of many of the American oil companies to secure control of foreign reserves on which to draw when our domestic supply begins its inevitable decline.

Active search was pushed energetically in many countries by American companies not previously holding foreign concessions. Geologic examinations, with some drilling, were extended to the Old World, ranging from Angola, on the west coast of Africa, to Sakhalin, off the east coast of Siberia. Mainly, however, the somewhat extensive territory leased at this time is confined to Mexico and South America, where the leased reserves are probably sufficient to supply a small nation for a long time, though the avenues of transportation may require protection in case of war. Certainly these reserves, unless too rapidly depleted, constitute a measure of insurance and should help to postpone the day of oil famine or onerous prices for oil in this country.

Meanwhile the campaign of education stimulated by the oil estimates quickened the realization both of a public formerly fatuously complaisant and of the Government that the prevention of needless

waste and the assurance of continuing adequate supplies of reasonably cheap oil is a concern of both the public and the state.

The ephemeral boom of oil-shale distillation for the production of substitutes for petroleum and its products, which occurred during the war period, may in part be credited as an unfortunate outcome of the oil-conservation publicity. Based only on preliminary examinations by the Government of the great deposits of oil shale in the Uinta Basin of Colorado, Utah, and Wyoming, on the fact that shales yielding not more than 20 gallons of oil to the ton had been treated with commercial success in Scotland, and on the not invariably scrupulous enthusiasm of a few visionary promoters, a large number of companies, estimated by Gavin[55] as over 100, were organized, and speculation in lands and stocks was wild.

Unlike the rich Paleozoic bogheads, canneloid coals, and very fatty shales utilized in Great Britain, France, and America between 1850 and 1859, the bituminous rocks used in the recent war period were in the main relatively lean shales of late Devonian or early Mississippian age in the Appalachian region and generally much richer oil shales of Tertiary Green River age in the Uinta Basin and in a small Tertiary basin at Elko, Nev. Some of the oil shale used was capable of producing 25 to 40 or even 85 gallons to the ton. A few small experimental plants, no two of which were alike, were built and tried for short periods. Only two of these plants can be regarded as trials on a commercial basis. The enterprises were almost entirely in the hands of men without experience in shale distillation or familiarity with any aspect of the problem. The bituminous rocks varied widely in both physical and chemical character; none used were like the Scotch shales, and no successful method of treatment had been devised in advance. The systematic and coördinated researches, possibly requiring years, which should have been made prior to and in preparation for the development of an oil-shale industry were in general neglected until the speculative bubble had burst.

One beneficial result of this abortive oil-shale boom was the withdrawal by the Government and segregation of oil-shale reserves in the Uinta Basin in Colorado and Utah from which the United States Navy may in some future time of trouble recover needed petroleum products—especially in case of war and military isolation, or when, in time of peace, the country may be drastically exploited by purveyors of foreign oil.

The relatively abrupt abandonment of the oil-shale activities was not wholly due to financial failures; it was due in part to the some-

[55] M. J. Gavin, "Oil Shale," *U. S. Bur. Mines Bull. 210* (1924), p. 98.

what enthusiastic psychology stimulated among American operators and technologists by European experimenters and proponents of low-temperature carbonization, high-temperature carbonization, hydrogenation and other modes of production of liquid hydrocarbons from coal, presented and discussed at the first International Conference on Bituminous Coals, held at Pittsburgh in 1926. The relative merits as well as the practical economies involved in the use of each of these processes have been very recently briefly discussed.[56]

It should be urged that making provision in advance against the day, certainly not long distant, when waning domestic petroleum reserves will fall shorter and still shorter of meeting American domestic needs, is not only natural and logical—it is fundamentally sound and necessary. If oil shales, of which the country has enormous reserves, apparently useless for other purposes, are to be utilized, their value, the most successful methods of treatment, the products that may be obtained, and the approximate cost of production should be learned in advance by research and experiment, which in the interest of the public should be carried on by the Government with such adequacy of financial support as the importance of the impending situation demands.

Two other causes besides the World War have contributed to the development of the recent surplus production of oil in the United States, though it is difficult to integrate their effects. One is the increase of knowledge of the geologic phenomena and conditions controlling the occurrence of petroleum; the other is the great advantages accruing to the producing companies through the utilization of this knowledge in the discovery and development of new oil fields. Most important to the progress in petroleum geology within the present century have been the development and application of geophysical, micropaleontologic, and micromineralogic methods of exploration in the search for and location of oil deposits, and the consequent rapidity with which new oil reserves have been found.

The theory accounting for the occurrence of oil and gas in anticlines and domes and the gravitational separation of the gas, oil, and water in the upper spaces of the reservoir was first clearly presented by T. Sterry Hunt, in 1861, after his examination of the oil wells in the western part of southern Ontario, the development of which on a commercial scale had been accomplished in 1859. Hunt's conclusion was:

These wells occur along the line of a low, broad anticlinal axis which runs

[56] "Review of the Petroleum Industry in the United States, April, 1934," *U. S. Geol. Survey Circ 11* (1934), pp. 37–39.

nearly east and west through the western peninsula of Canada. . . . The oil doubtless rises from the Corniferous limestone, which contains petroleum; this, being lighter than the water, which permeates at the same time the porous strata, rises to the higher portion of the formation, which is the crest of the anticlinal axis, where the petroleum of a considerable area accumulates and slowly finds its way to the surface through vertical fissures in the overlying Hamilton shales, giving rise to the oil springs of the region.[57]

Though accepted, after some delay, by most American geologists, the principle formulated by Hunt and Andrews less than 2 years after the drilling of the Drake well was given little consideration by the producing oil companies, even after its revival with greater emphasis by I. C. White, in 1883. On the contrary, the distribution of the first discovered pools in Pennsylvania in two northeast-southwest belts, as they were mapped in the 1860's, gave rise to the theories of "oil lines," to the effect that the oil occurred in belts conforming to zones of oil sand and even of underground streams of oil trending nearly N. 16° E.

Initially crude as was the "oil-line" theory,[58] which is now known to have some then unrecognized background in the trend of the Appalachian folds and ancient shore lines of the region, its foundation in circumstance and imagination is eclipsed by the theory, nearly contemporaneous in origin, of "oil lakes" and "oil rivers." The latter theory was based upon the large yield of some of the flowing wells, particularly wells like those in Tennessee and those discovered much later in the Tampico district of Mexico, where the oil apparently emerged under pressure from underground passages first formed by water and later gorged by petroleum, gas, and water under very great pressure. By the supporters of this highly promotional hypothesis the oil pools of the United States were fancifully represented on maps as tapping these great northeast-southwest oil rivers, tributaries, and underground lakes, some of which were represented as extending from Canada to Mexico. This theory still persists or, at least, was extant as

[57] Hunt published this extremely important conclusion in the *Canadian Naturalist* for August, 1861 (Vol. 6, pp. 245–255), but early in the same year he had stated the same conclusions in a lecture delivered before the Board of Arts of Montreal and reported in the *Montreal Gazette* of Mar. 1, 1861. Very soon after the latter date E. B. Andrews, in a paper on "Rock Oil, its Geological Relations and Distribution," published in the *American Journal of Science* for July, 1861, describing the occurrence of oil and gas springs in an anticlinal fold in Ohio, reached essentially the same conclusions. Further elaboration by Hunt of his views, which have since been proved in hundreds of oil fields, was made in a pamphlet on *Petroleum, Its Geological Relations*, published in Quebec in 1865. See F. D. Adams, *Biographical Memoir of Thomas Sterry Hunt* (Washington, 1932), p. 210.

[58] Nevertheless, it would seem that the pursuit of the "oil-line" theory probably led to the discovery and development of the Bradford region at a date much sooner than might otherwise have happened.

late as the period of the World War, and many landowners or companies were induced to make large expenditures in wildcatting lands supposed to be located over one of these oil rivers.

Meanwhile, notwithstanding its sound basis in theory, experiment, and field testing, the "anticlinal theory," urged by geologists,[59] was for nearly 50 years given little credence by the oil-company managements. Most of these companies continued, even in the early years of the present century, to locate test wells on the basis of the topography, on the advice of a superintendent of drilling or other nongeologic employee, or along the lucky strike of some "wildcatter." Some even depended on mere "hunches"; on witch-hazel and peach twigs and related methods, including numerous electrical devices bearing high-sounding names; on the advice of spiritualists and clairvoyants; or on "doodle-bugs" and dreams.

However, by 1908 a few companies were cautiously following geologic advice.[60] As the resulting economic advantages to these companies became quickly apparent and as the reports of the United States Geological Survey mapping the structure of the recently withdrawn public lands became known to them, other companies lost no time in adopting geologic guidance and methods of investigation. Large staffs were hastily recruited—to the depletion, first, of the geological surveys and bureaus of mines, and finally, of the university departments of geology.[61]

By 1915 few even among the small companies closed an option on or tested an isolated location that had not been mapped, with contouring of structure, by its geologists. Vast areas of possible oil-bearing territory in many states have thus been mapped after thorough geologic examination. Many areas were investigated and mapped again and again, each time by a different company, which as a rule kept the geologic findings secret.

At the same time the efficiency of the geologists in discovering

[59] A fuller account of the development of understanding of the principles of petroleum geology is given by J. V. Howell and others, in *Problems of Petroleum Geology*, edited by W. E. Wrather and F. H. Lahee (1934), pp. 3–96.

[60] So skeptical were some of the companies at the outset that the reports submitted by their geologists were "filed" and put to no use until several years later, when confidence had grown.

[61] In the period 1908–25, 55 geologists trained in petroleum geology resigned from the geologic service of the Government to enter oil-company employ or to open private offices as consulting specialists. Those first to resign entered the service of foreign companies for examinations in Mexico and other countries. During the period 1912–21, when the companies were most active in enlarging their staffs, not only were graduate students induced to enter company employ but many undergraduates in the departments of geology, paleontology, physics, and mineralogy were absorbed by the industry.

areas and localities that, in the light of the growing knowledge of oil geology, were regarded as favorable was greatly increased during and soon after the war by the use of geophysical instruments, especially instruments for measuring gravity, seismic or sonic apparatus, and the magnetometer. The first applications of gravimetry in the detection of anticlinal structure in this country were made in 1917 and 1919 by the United States Coast and Geodetic Survey, when stations profiling Damon Mound, in Texas, and the folds of Pennsylvanian age in western Maryland were occupied at the request of the United States Geological Survey.[62] The Eötvös torsion balance was used in the discovery of the Nash salt dome in Texas in 1924.

The adaptation and adoption of seismic methods in the same year proved especially advantageous, particularly in the Gulf Coastal Plain, where more salt domes were located in a few years than had been found in the preceding 30 years.

In the meantime it was shown that in some regions of relatively recent orogeny and rapid erosion the measurement of the temperature gradient in three or more pilot wells was helpful in determining the position of the axis of a concealed anticline. C. E. Van Orstrand, geophysicist of the Geological Survey, who in the course of his studies had measured the temperature gradients in many deep wells in different parts of the country as part of a study of the problem of the cooling earth, obtained evidence, notably in the Volcano anticline, near Fairmont, W.Va., that the temperature gradient steepens on approaching the axis of certain anticlines. This was brought to the attention of geologists by I. C. White,[63] who announced that

> The earth's temperatures under well-developed anticlinal axes are a few degrees higher at the same depths than where the strata are not arched or otherwise disturbed to any marked extent.

Later the question was somewhat extensively investigated, with measurement of temperatures of the wells in certain fields of Texas, Oklahoma, Kansas, New Mexico, Wyoming, and California, under the auspices of the American Petroleum Institute, with the advice of a research committee of the National Research Council. In general the results[64] are more or less conflicting, the success of the method being dependent on the region.

[62] David White, "Gravity Observations from the Standpoint of the Local Geology," *Geol. Soc. America Bull.*, Vol. 35, No. 2 (June 30, 1924), pp. 207–277, 1 pl.

[63] *Oil and Gas Men's Jour.*, Vol. 1 (1919), p. 22.
West Virginia Geological Survey County Reports (1919).

[64] Summarized in "Report on Fundamental Research in Petroleum," Pt. 3, *Bull. Am. Petroleum Inst.* (June 1932), pp. 16–20.

Airplane photographs in which many structural features hardly discernible at the surface of the ground are clearly shown, are now in wide use by the petroleum geologist, with consequent great gain in rapidity of discovery of new areas of favorable structure, as well as economy and ease of surveying in many regions.

Other important aids to the geologist in the determination of the geologic structure of a region, the identification of concealed formations, and the correlation of the oil sands from well to well and from field to field are micropaleontology, first developed in university and government laboratories and adopted by the oil companies in 1921, and micromineralogy, employed for the same purpose and organized in the oil-company staffs about 1925.

From the foregoing review of the outstanding features of oil-field development in the United States since 1900 it will be seen that, although the expansion of oil production was greatly stimulated by the demands imposed on producers during the World War, and by competition among the companies in leasing new territory after the estimates of 1916–22 as to the available oil remaining in the ground, the long-continued overproduction from which the industry has suffered is due chiefly to the development by geologists and the adoption by producing companies of scientific methods of exploration for oil and the consequent great rapidity with which new oil fields in large number have been located and, owing to prevalent methods of production, too promptly exploited.

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AGE AND CORRELATION OF PENNSYLVANIAN SURFACE FORMATIONS, AND OF OIL AND GAS SANDS OF MUSKOGEE COUNTY, OKLAHOMA[1]

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ABSTRACT

The Pennsylvanian formations of southeastern Oklahoma are correlated with those of northeastern Oklahoma. The Atoka, Hartshorne, McAlester, and Savanna formations and a portion of the Boggy shale—all of lower Pennsylvanian age—are directly traceable into the Winslow formation as heretofore mapped in the Muskogee Quadrangle. The upper sandstone member of the Savanna sandstone is equivalent to the Bluejacket sandstone member of the Cherokee shale on the north side of Arkansas River and is herein designated as the Bluejacket sandstone member of the Savanna sandstone. The outcrop equivalents of the oil and gas sands of western Muskogee County have been recognized.

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INTRODUCTION

The various sandstone members of the Atoka, Hartshorne, McAlester, and Savanna formations and a part of the Boggy shale have been traced recently from their type localities near McAlester, Oklahoma,[3] as far north as Arkansas River in Muskogee County. This tracing has been done in connection with detailed mapping of the coal and rock formations of portions of southeastern Oklahoma by the writer in 1929 and 1930 and by Thom and Hendricks in adjoining areas on the south.

[1] Manuscript received, April 1, 1933; revised, January 17, 1935. Published with the permission of the director of the United States Geological Survey.

[2] Vanderbilt University. Introduced by L. C. Glenn.

[3] J. A. Taff, "Geology of the McAlester-Lehigh Coal Field, Indian Territory," *U. S. Geol. Survey Nineteenth Ann. Rept.* (1898), Pt. 3, pp. 436–38.

AGE AND CORRELATION OF PENNSYLVANIAN FORMATIONS OF MUSKOGEE COUNTY

The sequence of the formations and their subdivisions as they have been recognized by Thom in the Quinton-Stigler-Poteau district and by the writer in the Muskogee-Porum district is as follows.

Boggy shale	Taft sandstone member Shale Inola limestone member* Shale Crekola sandstone member Shale
Savanna sandstone	Bluejacket sandstone member Shale Spiro sandstone member Sam Creek limestone member* Shale Spaniard limestone member† Keota sandstone member Shale Tamaha sandstone member
McAlester shale	Shale Cameron sandstone member Shale Lequire sandstone member Shale Warner sandstone member McCurtain shale member
Hartshorne sandstone	
Atoka formation	Shale Blackjack School sandstone member Shale Webbers Falls sandstone member Shale Dirty Creek sandstone member Shale Georges Fork sandstone member Shale Pope Chapel sandstone member Shale Coata sandstone member
Morrow formation	

* Name used by Lowman[4] in referring to an outlier of this limestone member on a hill east of Inola, Oklahoma.

The Sam Creek limestone member was named by Lowman[5] from an exposure in the center of the west half of the east half of Sec. 15, T. 14 N., R. 18 E. along the south bank of Sam Creek, Muskogee County. Lowman's description of this limestone member is quoted on page 510.

† The Spaniard limestone member was named by Lowman[5] from an exposure in Spaniard Creek, Muskogee County (SW. ¼, NE. ¼, Sec. 11, T. 13 N., R. 18 E.) Lowman's description of this limestone member is quoted on page 510 of this report. This description is taken from a manuscript now in preparation.

[4] Shepard W. Lowman, "Lower and Middle Pennsylvanian Stratigraphy of Oklahoma East of the Meridian and North of the Arbuckle Mountains," *Tulsa Geological Society Summaries and Abstracts of Technical Papers* (1932).

[5] *Idem*, manuscript now in preparation.

[6] *Idem*, "Cherokee Structural History in Oklahoma," *Tulsa Geological Society Digest* (1933).

Atoka formation.—The shales and sandstones of the Atoka formation lie between the top of the Morrow formation and the base of the Hartshorne sandstone. There is an unconformity between the Morrow

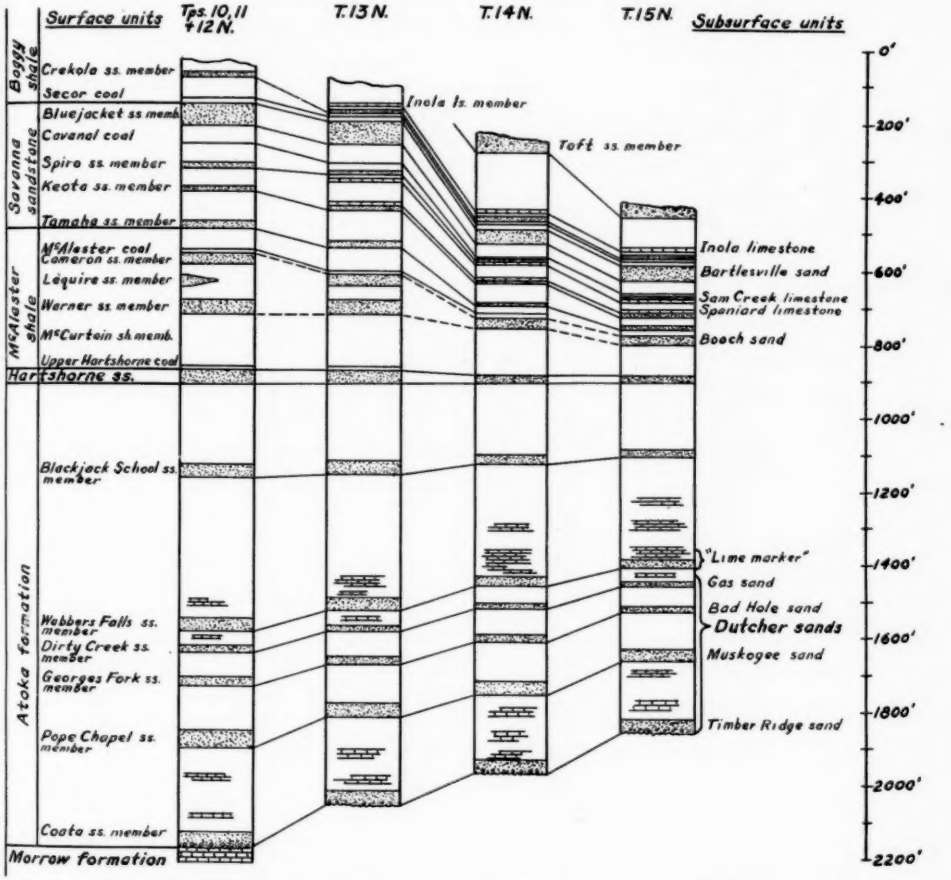

FIG. 1.—Columnar sections of lower Pennsylvanian rocks of Muskogee County, Oklahoma, showing members of formations present, and correlation of surface units with subsurface units.

and Atoka formations, as is shown by the stratigraphic relations of the two formations north and east in Oklahoma and Arkansas. This break in the Muskogee area is ordinarily marked by a basal sandstone (Coata sandstone member) made up of quartz grains, ranging up to

3 mm. in diameter. At one exposure in the northern part of Sec. 35, T. 15 N., R. 19 E., this sandstone contains chert pebbles as much as 1 inch in diameter that were probably derived from the Mississippian Boone limestone.

The Atoka formation includes at least six traceable sandstone members, each overlain by shale (Fig. 1). Logs of wells drilled through the formation indicate variations in thickness and extent of some of the sandstone members, as is shown by the lensing of some of the lower sandstones and the occurrence of "stray sands." The total thickness ranges from an average of 1,260 feet in T. 10 N., to 950 feet in T. 15 N.

SECTION OF ATOKA FORMATION, COMPILED FROM TYPICAL EXPOSURES IN MUSKOGEE COUNTY

	Feet
Fissile shale, dark blue-to-black; contains iron concretions	150– 220
Blackjack School sandstone member (named from exposures at and around Blackjack School, in Sec. 9, T. 11 N., R. 19 E.) Thin-to-massive-bedded sandstone; medium to fine-grained; commonly greenish brown (due to presence of iron silicates) on fresh surface, weathering to dirty yellowish brown, but in places white-to-light brown on fresh surfaces; grades downward into sandy shale; fossiliferous	25– 40
Shale, usually concealed	150– 350
Webbers Falls sandstone member (named from exposure in Secs. 10 and 15, T. 12 N., R. 20 E., about 2 miles west of Webbers Falls) Impure bluish calcareous sandstone, contains angular quartz grains and argillaceous and carbonaceous matter; fossiliferous	35
In southern part of county, lower portion of Webbers Falls sandstone member crops out as thin-bedded, blocky, impure sandstone, which has fine-grained texture and is dark blue on fresh surfaces, weathering to alternating bands of light blue and brown. Microscopic examination of thin sections reveals fact that echinoid spines in sandstone have been replaced by chalcedony. This process of leaching of calcareous material and replacement by chalcedony has probably taken place only near surface. Characteristics here given indicate that this rock was originally calcareous sandstone. Exposures of massive, coarse-to-medium-grained sandstone are found locally in this sandstone member in Secs. 11 and 34, T. 12 N., R. 19 E.	
Ledge of limestone crossing Arkansas River at Webbers Falls is believed to belong to this member	
Fissile shale; dark blue, contains a few calcareous layers	40
Dirty Creek sandstone member (named from exposure west of Dirty Creek in Secs. 11 and 14, T. 12 N., R. 19 E.) Thin-to-massive-bedded sandstone; fine-grained; dark blue; color changes from blue to brown and texture from fine to medium-grained as one traces the sandstone from south to north; bottom surfaces of sandstone beds are covered with "fucoidal" markings, similar to *Taonurus caudagalli*, fossiliferous	5– 20
Fissile, varicolored shale	60
Georges Fork sandstone member (named from exposure east of Georges Fork in Secs. 24 and 25, T. 12 N., R. 19 E.) Thin-to-massive-bedded sandstone; medium-grained; commonly greenish brown on fresh surfaces, weathering to brown; bottom surfaces of sandstone beds covered with "fucoidal" markings, as in Dirty Creek member; fossiliferous	35
Shale, usually concealed	80– 120

Pope Chapel sandstone member (named from exposure at Pope Chapel in Sec. 24, T. 12 N., R. 19 E.)		
Massive-to-irregularly bedded sandstone; coarse-to-medium-grained; saccharoidal; highly colored, usually red, brown, yellow, or white; contains clay blebs		50
Fissile, gray shale, with many calcareous layers	150–	220
Coata sandstone member (named from exposure along Coata Creek in Secs. 34 and 35, T. 15 N., R. 19 E.)		
Massive sandstone; medium-to-coarse-grained, containing large pebbles of quartz and chert near base; light-to-dark brown; fossiliferous		40
	820–	1,130

Hartshorne sandstone.—The Atoka formation is overlain conformably by the Hartshorne sandstone, which is composed of a single sandstone that lies between the shale above the Blackjack School sandstone member of the Atoka and the McCurtain shale member of the McAlester shale. The total thickness of the Hartshorne sandstone varies from 35 feet in the southern part of the county to about 15 feet in the northern part.

The sandstone is usually regularly bedded. The beds are ordinarily thin and slabby, usually 1–6 inches thick but at some places as much as 2 feet thick. Cross-bedding and ripple marks are locally abundant. The texture is usually fine but is sometimes medium in grain. The color is white and gray on fresh surface, weathering to a light brown. The whiteness of the sandstone makes the formation easy to recognize. Numerous wavy, dark streaks of argillaceous material containing mica flakes, occur in the sandstone. Plant remains are abundant.

McAlester shale.—The shales and sandstones of the McAlester shale overlie the Hartshorne sandstone conformably, and their maximum thickness shown in well logs varies from 500 feet in T. 10 N. to 150 feet in T. 15 N. Surface measurements vary between 382 feet in T. 10 N. and 125 feet in T. 15 N. The formation contains the McAlester, or Stigler, coal bed, and the Upper Hartshorne coal, which occurs near the base of the formation, from a few inches to 4 feet above the Hartshorne sandstone. The McAlester shale includes four recognizable members (Fig. 1).

SECTION OF MCALESTER SHALE, COMPILED FROM TYPICAL EXPOSURES IN SOUTHERN PART OF MUSKOGEE COUNTY

	Feet	*Inches*
Dark, carbonaceous shale	70	
Calcareous shale; fossiliferous		4
McAlester (Stigler) coal (not found north of Sec. 13, T. 14 N., R. 18 E.)	1	6
Gray shale	1	10
Cameron sandstone member (named for exposures northwest and west of Cameron, in T. 8 N., R. 26 E., in area mapped (unpublished) by W. T. Thom, Jr.)		
Commonly thin and regularly bedded, but locally massive and irregularly bedded; fine-to-medium texture; usually light gray, but in places brown (especially where massive); ripple marks common; fossiliferous	20	

Light brown, sandy shale	40	
Lequire sandstone member (named for exposures a little north of Lequire in Secs. 4 and 5, T. 7 N., R. 21 E., and Secs. 32, 33, and 34, T. 8 N., R. 21 E., in area mapped (unpublished) by W. T. Thom, Jr.)		
Massive sandstone; medium texture; friable; brown-to-gray; contains plant remains	25	
Shale, usually concealed	40	
Warner sandstone member (named from exposure 1 mile north of Warner)		
Massive, very irregularly bedded sandstone; medium texture; friable; brown; cross-bedded; contains clay blebs; very ferruginous, with numerous reticulate networks of limonitic ribbons; white mica common; plant fossils present	40	
McCurtain shale member (named for fact that part of McCurtain, Haskell County, is built on this shale. Type locality is in area mapped (unpublished by W. T. Thom, Jr.)		
Fissile, dark blue shale; contains layers of iron concretions	130	
Calcareous shale		10
Shale	7	
Upper Hartshorne coal (not found north of T. 12 N.)		10
Sandy shale; contains many plant fragments	4	10
	382	2

Savanna sandstone.—This formation overlies the McAlester shale conformably and includes the sandstones and shales lying between the bottom of the Tamaha sandstone member and the top of the Bluejacket sandstone member. Four sandstone members were recognized in this formation by the writer (Fig. 1). Another sandstone member, which lies in the interval between the Spiro sandstone member and the Bluejacket sandstone member of the Quinton-Stigler-Poteau district, is not recognizable in Muskogee County, but a representative of it is probably present, although it has not been separated from the Bluejacket sandstone member. The shale above the Spiro sandstone member contains the Cavanal coal. The thickness of this formation ranges from 332 feet and 10 inches in T. 10 N. to 170 feet in T. 15 N.

Two limestone members are present within the Savanna sandstone as far south as T. 13 N. These thicken northward. In T. 13 N. they average approximately 10 inches in thickness and are separated by about 60 feet of shale. The lower of the two, the Spaniard limestone member, lies immediately on the Keota sandstone member. The upper limestone, the Sam Creek limestone member, lies very close below the Spiro sandstone member.

Several previous writers predicate an unconformity at a horizon which the present writer correlates as being near the base of the Bluejacket sandstone member. The writer was unable to find any evidence of an unconformity at this horizon. Small, local unconformities, or diastems, are, no doubt, to be found within this formation; but no well developed unconformity was found. On the contrary, the entire Savanna sandstone and the lower part of the Boggy shale have been

offset by the major faults in the county. It is assumed, therefore, that movements along these faults, as expressed in the surface strata, took place largely at some time after the deposition of the Savanna sandstone. If the structures do extend westward beneath the gently dipping Bluejacket sandstone member (as was suggested by some of the previous writers), it is because of recurrent movements which took place during the deposition of the underlying formations and which were not of sufficient intensity to produce a marked break. The writer does not believe that the underlying formations and the lower part of the Savanna were folded and faulted, then eroded to form an unconformity near the middle of the Savanna, and later covered by the upper part of the Savanna.

SECTION OF SAVANNA SANDSTONE, COMPILED FROM TYPICAL EXPOSURES IN SOUTHERN PART OF MUSKOGEE COUNTY

	Feet	*Inches*
Bluejacket sandstone member (well exposed along Emachaya Creek near Enterprise, T. 9 N., R. 18 E., in area mapped (unpublished) by W. T. Thom, Jr.)		
Massive, irregularly-to-regularly bedded sandstone; medium texture; friable; very light brown to almost white in color; cross-bedded; contains many grains of feldspar and very little ferruginous material; weathered joint blocks more or less rounded by exfoliation	60	
Brown, micaceous, sandy shale	50	
Cavanal coal		10
Brown shale	60	
Spiro sandstone member (caps ridge in Secs. 13 and 14, T. 9 N., R. 25 E., just north and northeast of Spiro, LeFlore County, in area mapped (unpublished) by W. T. Thom, Jr.)		
Brown sandstone; regularly bedded; blocky; fine-to-medium texture; contains plant fossils west of Porum	12	
Brown, sandy shale	50	
Keota sandstone member (named for exposures at Keota, Haskell County, in area mapped (unpublished) by W. T. Thom, Jr.)		
Gray-to-brown sandstone; regularly bedded; blocky; ripple-marked		10
Shale, usually concealed	70	
Tamaha sandstone member (named for exposures at Tamaha, Haskell County, in area mapped (unpublished) by W. T. Thom, Jr.)		
Thin-bedded, slabby sandstone, rarely massive; bedding regular; fine-to-medium texture; color brown, in places greenish brown and gray, weathering to dark brown; contains much mica and many dark, argillaceous streaks; ripple marks abundant	20	
	332	10

SECTION OF SAVANNA SANDSTONE, COMPILED FROM TYPICAL EXPOSURES IN NORTHERN PART OF MUSKOGEE COUNTY

	Feet	*Inches*
Bluejacket sandstone member	40	
Black shale	40	
Cavanal coal		10
Shale	5	
Spiro sandstone member		
Thinly bedded, argillaceous sandstone	10	
Buff shale	3	

	Feet	Inches	Feet	Inches
Sam Creek limestone member (named by Lowman from exposure along Sam Creek in Sec. 15, T. 14 N., R. 18 E. Following description of limestone is taken from manuscript now in preparation by Lowman)				
Gray limestone; weathers brown; contains so many *Marginifera muricata* that it is almost coquina		6		
Gray, fossiliferous shale	3	6		
Alternation of gray limestone and gray, fossiliferous shale, the former essentially a reef composed of *Campophyllum torquium*		11		
Gray limestone, with layers of gray shale	3	8		
Total			8	7
Shale			40	
Spaniard limestone member (named by Lowman from exposure on Spaniard Creek, Muskogee County (SW. ¼, NE. ¼, Sec. 11, T. 13 N., R. 18 E.) Following description of limestone is taken from a manuscript now in preparation by Lowman)				
Dark gray, fine-grained limestone; weathers brown	1	2		
Dark gray-to-black, fossiliferous shale, weathers buff		6		
Blue-gray, fossiliferous, calcareous shale	1	6		
Total			3	2
Keota sandstone member				
Thinly bedded, slabby sandstone, with layers of sandy shale	10			
Shale	35			
Tamaha sandstone member	10			
			205	7

Boggy shale.—Only the lower part of this formation crops out in Muskogee County. This part of the Boggy extends upward from the top of the Bluejacket sandstone member of the Savanna sandstone and includes the Crekola and Taft sandstone members, the Inola limestone member, and intervening shale beds. The shale between the Bluejacket sandstone member of the Savanna sandstone and the Crekola sandstone member contains the Secor or Upper Witteville coal. The writer believes that the Boggy shale overlies the Savanna sandstone conformably in this county rather than unconformably, as it is known to do in the extreme southwestern point of the coal basin.[7] This unconformity is known only in the part of the coal basin where the influence of elevation in the Arbuckle mountain area is apparent. It is probable that Muskogee County lay entirely beyond the influence of elevation in the Arbuckle Mountains and that the Boggy is conformable with the underlying Savanna sandstone in this area.

LOWER PART OF BOGGY SHALE, EXPOSED IN MUSKOGEE COUNTY

	Feet	Inches
Taft sandstone member (named from exposures south of Taft, Sec. 19, T. 15 N., R. 17 E.)		
Massive gray-to-light brown sandstone; contains small		

[7] G. D. Morgan, "Boggy Unconformity and Overlap in Southern Oklahoma," *Bureau of Geology* (Norman, Oklahoma) *Circular No. 2* (1924).

pebbles of quartz in T. 14 N., and large pebbles of sandstone, shale, and quartz in southwest corner of T. 15 N. This conglomerate was not found north of Arkansas River; hence might represent shore phase of the member	50	
Brown, micaceous, sandy shale	80–150	
Inola limestone member (name used by Lowman in referring to outlier of this limestone member on hill east of Inola, Oklahoma. See footnote on page 504)		
Massive, dark blue limestone, containing many fossils among which are large sponges		10
Black shale	10	
Crekola sandstone member (named for fact that village of Crekola, in east ½ of Sec. 10, T. 14 N., R. 17 E., is located on this sandstone)		
Brown sandstone; regularly bedded; blocky; medium texture	10	
Sandy shale	5	
Dark shale containing fossils	1	
Secor coal, with thin dirt band near middle	1	1
Shale	15	
	172 ft. 11 in.–242 ft. 11 in.	

In Figure 2 the outcrop of the base of the Bluejacket sandstone, which in this area is the topmost member of the Savanna sandstone, is shown from Arkansas River southward to the northeast corner of the McAlester Quadrangle. Southward from this locality it dips under the Sanbois syncline, but it occupies the same stratigraphic position as the uppermost sandstone of the Savanna on the south side of the syncline, which was found by T. A. Hendricks to be continuous to the type section of the Savanna.

Similarly, the outcrop of the Warner sandstone member of the McAlester shale is shown. The outcrop traces of this sandstone east and south of Stigler also are included on the map. In the Quinton-Stigler-Poteau district the outcrop of this sandstone has a broken and tortuous course back and forth across Arkansas River, following the numerous faults and folds of that region.

The exposures and outcrops of the Inola limestone member of the Boggy shale and of the Spaniard and Sam Creek limestone members of the Savanna sandstone are also shown south of Arkansas River.

SUBDIVISIONS OF WINSLOW FORMATION AS HERETOFORE MAPPED IN MUSKOGEE COUNTY

As a result of the studies by the writer, the rocks mapped in Muskogee County as Winslow formation on the State geological map have been subdivided into units here designated as the Atoka, Hartshorne, McAlester, and Savanna formations, and the lower part of the true Boggy shale. The Savanna sandstone is shown on the State geological map to thin and disappear in T. 12 N., R. 19 E. Actually,

however, the true equivalent of the Savanna sandstone of the McAlester district has been mapped by the present writer as far north as Arkansas River in Muskogee County, but had previously been included in the Winslow formation.

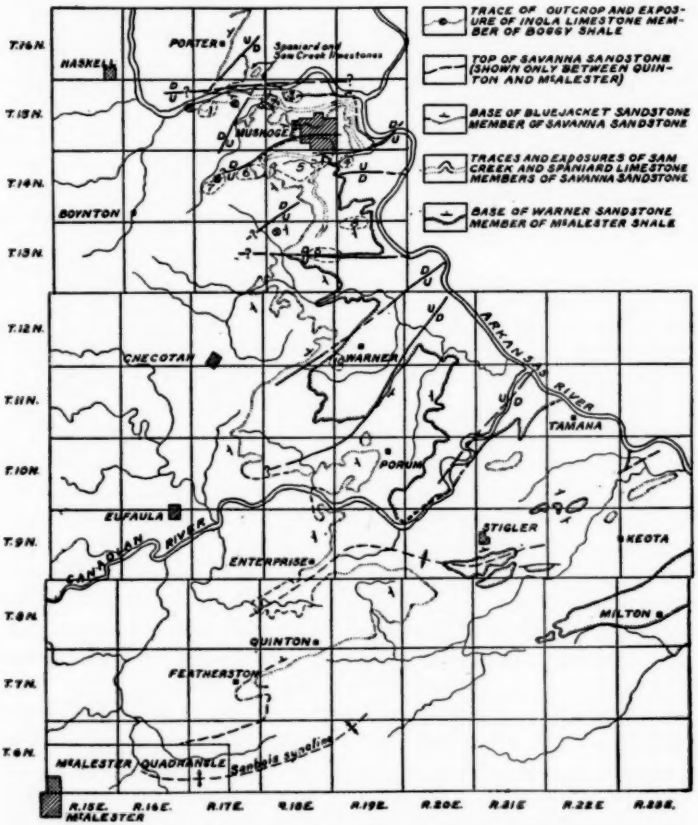

FIG. 2.—Map of part of east-central Oklahoma, showing in part outcrop of base of Bluejacket sandstone member of Savanna sandstone; base of Warner sandstone member of McAlester shale; Sam Creek and Spaniard limestone members of Savanna sandstone; and Inola limestone member of Boggy shale. Map constructed from data compiled by W. T. Thom, Jr., in Quinton-Stigler-Poteau district and by C. W. Wilson, Jr., in Muskogee-Porum district.

Index to Oil and Gas Fields

1. Sommerville
2. Robinson
3. Lampton
4. Jolly-Patton
5. Muskogee
6. Timber Ridge
7. Beland
8. Brushy Mountain
9. Keefeton
10. Warner

AGE AND CORRELATION OF CHEROKEE SHALE

North of Arkansas River the Cherokee shale, as mapped, lies between the Fort Scott limestone and the Morrow formation or some lower formation where the Morrow is absent. South of the river it includes the strata between the base of the Wetumka shale[8] and the top of the Morrow formation. Correlations of the Cherokee shale of northeastern Oklahoma with the formations described by Taff in the McAlester district have been many and varied. No attempt will be made to summarize these correlations.

The northward tracing of the Atoka, Hartshorne, McAlester, Savanna, and Boggy formations to Arkansas River in Muskogee County affords new information as to the southern correlatives of the Cherokee shale. It seems probable that they each have equivalents in the lower part of the Cherokee shale. The Thurman, Stuart, Senora, and Calvin formations were not studied by the writer and he therefore obtained no information that may bear on whether they are wholly, or in part, cut out by unconformities or overlap, or whether these formations are all represented in the upper part of the Cherokee.

A detailed section of the Cherokee shale measured at Pryor, Oklahoma, by Ireland[9] shows the formation to be about 1,000 feet thick. Of this total thickness about 580 feet overlies the Bluejacket sandstone member and about 360 feet underlies this member. If, as the present writer believes his field work proves, the correlation of the uppermost sandstone member of the Savanna sandstone with the Bluejacket sandstone member of the Cherokee shale is correct, the lower part of the Cherokee shale at Pryor is composed of 360 feet of strata that are the thinned equivalents of parts or all of the Atoka formation, Hartshorne sandstone, McAlester shale, and that part of the Savanna sandstone that underlies the Bluejacket sandstone member. Similarly, the upper part of the Cherokee shale at Pryor contains about 580 feet of strata that are the thinned equivalents of parts or all of the Calvin, Senora, Stuart, Thurman, and Boggy formations. The thinning and convergence of these formations from T. 6 N. northward to T. 29 N. are shown in Figure 3.

The northward thinning of the Savanna, McAlester, Hartshorne, and Atoka formations, which form the lower (Bluejacket and sub-Bluejacket) part of the Cherokee shale, is from approximately 10,000 feet in the McAlester district,[10] to 4,250 feet in the Stigler-Poteau

[8] Edward Bloesch, "Fort Scott-Wetumka Correlations," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), pp. 810–11.

[9] H. A. Ireland, "Oil and Gas in Oklahoma, Mayes County," *Oklahoma Geol. Survey Bull. 40*, Vol. 3 (1928), pp. 26 and 27.

[10] T. A. Hendricks, personal communication.

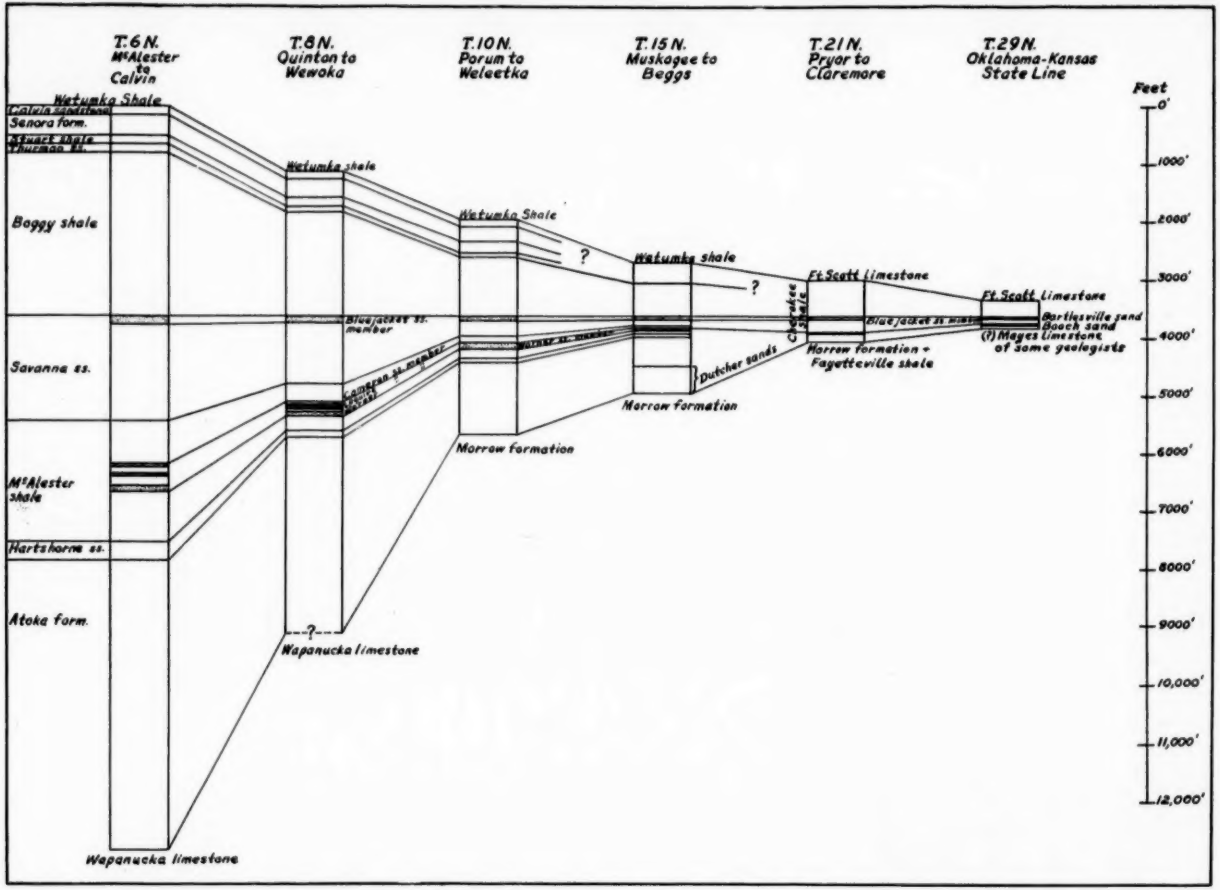

FIG. 3.—Sections showing thinning and convergence of formations between Wetumka shale and Wapanucka limestone north of T. 6 N., and their correlation with Cherokee shale in T. 29 N. Thicknesses in T. 6 N. were furnished by T. A. Hendricks; those in T. 8 N. by W. T. Thom, Jr.; those in Ts. 10 and 15 N. up into Boggy shale were measured by C. W. Wilson, Jr.; those in T. 21 N. were measured by H. A. Ireland; and remainder were compiled from miscellaneous well logs and sections.

district;[11] to 1,500 feet in Muskogee County; to 420 feet at Pryor, Oklahoma, as measured by Ireland.

AGE AND CORRELATION OF OIL AND GAS SANDS OF MUSKOGEE COUNTY

One of the significant results of the study of the formations cropping out at the surface in Muskogee County has been the determination of the ages of the many oil and gas sands of that county. This determination will aid greatly in the proper age assignments of sands encountered in oil and gas fields of northeastern Oklahoma west and northwest of Muskogee County.

In wells drilled in the western part of Muskogee County the following Pennsylvanian horizons are encountered: Bartlesville sand, Booch sand, "Lime marker," and Dutcher sands. The correlation of these subsurface horizons with the surface rock units is shown in Figure 1.

Dutcher sands.—The Dutcher group of sands includes several sands which belong to the Atoka formation. In Muskogee County this group is composed of four sands, which, according to drill records, are irregular in extent and thickness and include local "stray sands." Such irregularities noted by drillers are not apparent at the surface and hence the writer believes that the irregularities postulated by drill records result to a large extent from inaccuracies in logging.

The subsurface sands of Muskogee County and their surface equivalents in the Atoka formation are as follows.

Sand	*Sandstone member of Atoka formation*
Gas sand	Dirty Creek sandstone member
Bad Hole sand	Georges Fork sandstone member
Muskogee sand	Pope Chapel sandstone member
Timber Ridge sand	Coata sandstone member

The Pope Chapel sandstone member (Muskogee sand), which belongs to the Dutcher group of sands, is made up of angular, rarely subangular, grains of clear, colorless quartz, many of which have well developed crystal faces, and some of which are almost perfect crystals; it is an exceedingly "clean" sand, containing practically no accessory minerals; its grains are locally partly coated with red, brown, and yellow iron oxides, which serve both as cementing matter and coloring agents; the grains vary between .25 and .5 mm. in diameter, and average approximately .35 mm.

The angularity and the interlocking character of the grains and the marked development of crystal faces is due to the secondary en-

[11] W. T. Thom, Jr., personal communication.

Ts. 10 and 15 N. up into Boggy shale were measured by C. W. Wilson, Jr.; those in T. 21 N. were measured by H. A. Ireland; and remainder were compiled from miscellaneous well logs and sections.

largement of the grains. The secondary border surrounding the original grain is optically continuous with that grain. The secondary enlargement is recognized in the thin sections by the thin, dark boundary line between the original and secondary quartz, by the fewer minute inclusions in the secondary border, by the way in which the grains are intergrown, and by the change in outline from the original subangular grain to the more or less complete crystal shape.

"Lime marker."—The "lime marker," which is logged above the Dutcher sands in Muskogee County, is partially the subsurface equivalent of the Webbers Falls sandstone member of the Atoka formation. When fresh, this member is a dark blue, hard, calcareous shale. After exposure at the surface the calcium carbonate is commonly leached out, leaving a gray, hard, siliceous shale. The calcareous shale immediately overlying the Webbers Falls member is in some places logged with the member as a part of the "lime marker."

Booch sand.—The Booch, Taneha, or Tucker sand is here correlated with the Warner, Cameron, and Lequire sandstone members of the McAlester shale. This sand has formerly been correlated with the Hartshorne sandstone by some workers, and with sandstone members of the McAlester shale by others. The northward surface tracing of these sandstone members by Thom, Hendricks, and the writer from their type localities, and the subsurface correlation of this sand from the oil and gas fields west and northwest of Muskogee County, demonstrate definitely the correlation of the Booch sand with the Warner, Cameron, and Lequire sandstone members of the McAlester shale.

The interval between the Booch sand and the Bartlesville sand (Bluejacket sandstone member of the Savanna sandstone) as measured at the surface in Muskogee County averages 350 feet in Ts. 10, 11, and 12 N.; 330 feet in T. 13 N.; 200 feet in T. 14 N.; and 150 feet in T. 15 N. The interval between the Booch sand and the top of the Morrow formation as measured at the surface in Muskogee County averages 1,440 feet in Ts. 10, 11, and 12 N.; 1,320 feet in T. 13 N.; 1,200 feet in T. 14 N.; and 1,050 feet in T. 15 N.

The Booch sand is described as follows: angular grains of clear, colorless quartz with many well developed crystal faces, due to secondary enlargement of the original subangular grain, and a few subangular grains composed of an aggregate of argillaceous material; contains many flakes of white mica; very ferruginous; cemented and colored by a light-to-dark brown coating; grains vary between .1 and .5 mm. in diameter, and average approximately .3 mm.

Bartlesville sand.—The subsurface correlation of the Bartlesville sand with the Salt sand of the Okmulgee district and the Glenn sand

of Glenn pool has long been recognized. This sand horizon has been correlated with the Savanna sandstone by many writers, but with sandstone members of the McAlester shale by other writers. As a result of the work of Thom, Hendricks, and the writer, the uppermost sandstone member of the Savanna sandstone has been traced from the type locality of the Savanna sandstone northward to Arkansas River and there correlated with the Bluejacket sandstone member of the Cherokee shale on the north side of the river. The Bluejacket sandstone member, which is the surface equivalent of the Bartlesville sand, is therefore here demonstrated to be the uppermost sandstone member of the Savanna sandstone on the south side of Arkansas River and is here designated as the Bluejacket sandstone member of the Savanna sandstone south of the river.

The Inola limestone member of the Boggy shale, which is found by surface measurement to be about 40 feet above the top of the Bluejacket sandstone member, occurs only as far south as Sec. 7, T. 13 N., R. 18 E. North of that locality scattered exposures of the limestone are to be found. This limestone in Ts. 13, 14, and 15 N., Rs. 17, 18, and 19 E., is a massive, hard, dark blue limestone, containing numerous fossils, among which a large variety of sponges is characteristic. The thickness averages approximately 10 inches.

The Spaniard and Sam Creek limestone members of the Savanna sandstone are found as far south as T. 13 N., R. 18 E. The Sam Creek limestone member lies lower than the Bluejacket sandstone member by about 100 feet in T. 13 N. and about 50 feet in T. 15 N. The Spaniard limestone member lies about 160 feet below the Bluejacket sandstone member in T. 13 N. and 80 feet in T. 15 N., and varies between 60 and 30 feet below the Sam Creek limestone member. The writer would here like to acknowledge his indebtedness to S. W. Lowman for demonstrating the significance of these three limestone members in the correlation of the Bartlesville sand with its surface equivalent, the Bluejacket sandstone member.

In those localities west and northwest of Muskogee County, where the Bartlesville sand is logged as being appreciably thicker than 40 feet, it is possible that a portion of the 40 feet of Boggy shale that lies between the Inola limestone member and the Bluejacket sandstone member, and that a portion of the 50–100 feet of Savanna sandstone lying between the Sam Creek limestone member and the base of the Bluejacket sandstone member, are locally sandy and hence have been logged with the normal 40 feet of the Bluejacket sandstone. This interval between the Inola limestone member and the Sam Creek limestone member also includes the Crekola sandstone member of the

Boggy shale and the Spiro sandstone member of the Savanna sandstone.

The Bartlesville sand (Bluejacket sandstone member) is described as follows: angular grains of clear quartz, which have been secondarily enlarged; contains many subangular grains of plagioclase feldspar, both fresh and decomposed, and many white mica flakes; contains very little iron coloring matter; the grains of quartz and feldspar vary between .1 and .25 mm. in diameter and average approximately .2 mm.

OIL AND GAS FIELDS OF MUSKOGEE COUNTY

Muskogee County was first tested for oil and gas in the townsite of Muskogee in 1894. The resulting pool, however, was not developed until 1904, because of the difficulty of securing lawful land titles. Since that date the county has been prospected with varied, but never spectacular success. At the present time ten oil and gas fields are active. The locations of these fields are shown in Figure 2.

Most of the production of the oil and gas fields in Muskogee County is from the Dutcher series of sands, of which the Muskogee and Timber Ridge sands are of greatest importance. The depths to the productive sands in the various fields are shown in Figure 4 by representative logs. Where possible the writer chose logs that were drilled as deep as the Arbuckle limestone in order to show the various subsurface rock units encountered in drilling in each of the fields. As this report is intended to cover only the Pennsylvanian surface and subsurface formations, a discussion of the pre-Pennsylvanian formations will not be included. For descriptions of these units the reader is referred to the report by Soyster and Taylor on the oil and gas in Muskogee County, published in 1930 as part of *Bulletin 40* of the Oklahoma Geological Survey.

The oil and gas fields of Muskogee County may be divided into two groups on the basis of structure. First are those developed on small local anticlines which have no direct bearing on the regional structure. This type includes the Sommerville, Robinson, Jolly-Patton, Brushy Mountain, and Lampton fields.

The second group are those fields developed along monoclinal folds associated with the large normal faults that divide Muskogee County into six crustal blocks. The faulting in this area probably originated in the competent basement rocks of pre-Cambrian age, and resulted from differential uplift of the Ozark dome. These faults were reflected upward into the overlying brittle, incompetent sedimentary strata that probably draped over the underlying faults as

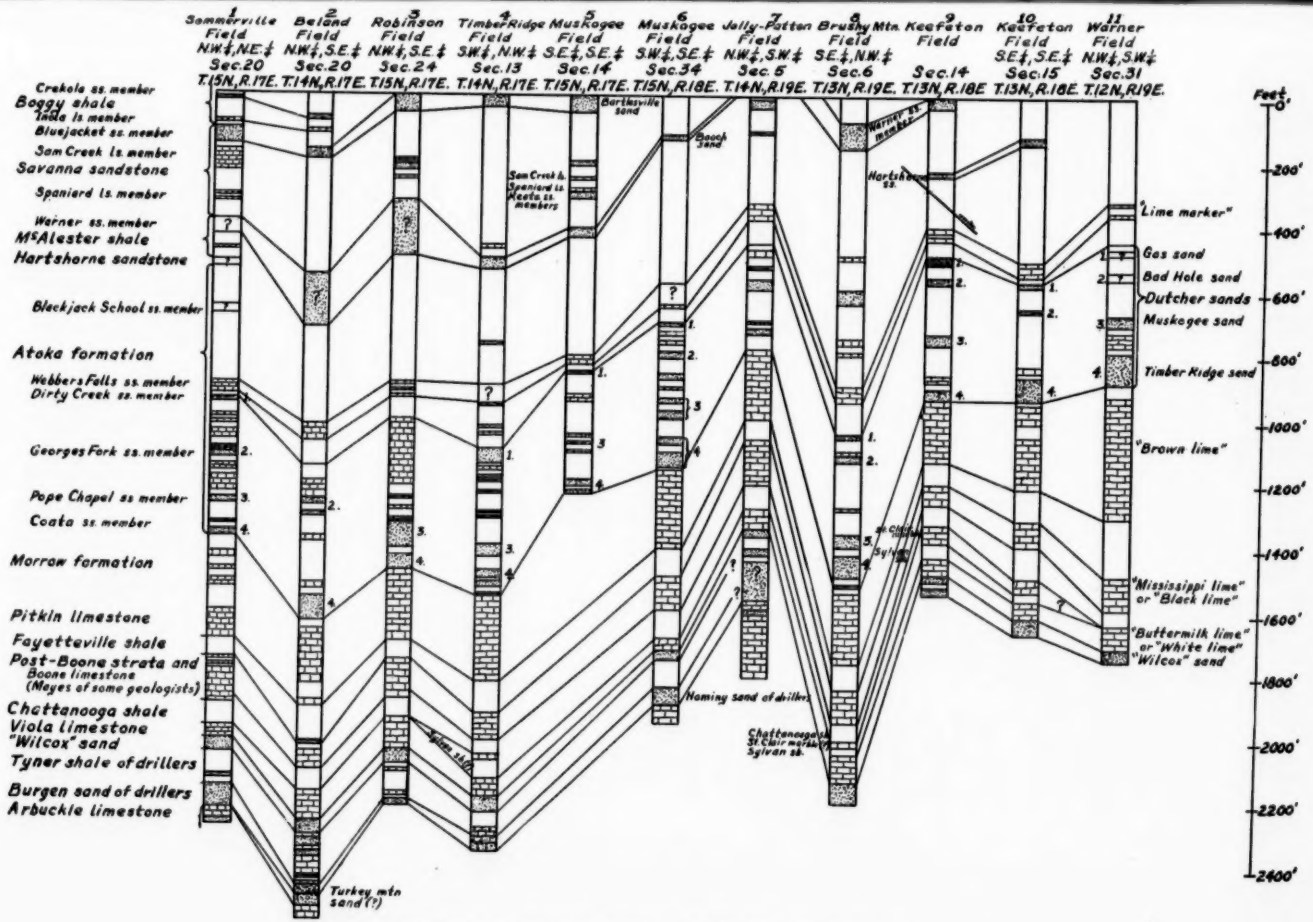

FIG. 4.—Typical well logs from oil and gas fields of Muskogee County.

monoclinal folds, which were ruptured by continued movement along the fault planes.

This type includes the Muskogee, Timber Ridge, Beland, Keefeton, and Warner fields.

One of the most interesting fields in the county is the Keefeton gas field. This field has been developed along a faulted monoclinal fold (Keefeton fault) whose axis trends east and west, crossing the county near the center of T. 13 N., Rs. 18 and 19 E. The maximum throw, which is between Sec. 15, T. 13 N., R. 19 E. and Sec. 17, T. 13 N., R. 18 E., is 600 feet or more. The down-throw side is on the north.

The dip of the plane of this fault is as low as 60 degrees in Secs. 13 and 14, T. 13 N., R. 18 E. Wells drilled in these sections and in Secs. 17, 18, 19, and 20, T. 13 N., R. 19 E., on the downthrown side of the fault, and within a half mile of its outcrop, cut the fault plane and strike the gas horizons at approximately the same depths as wells begun on the upthrown side of the fault plane. Some of the logs, which intersect the fault plane, have been shortened as much as several hundred feet. This is shown in log 10 of Figure 4.

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WHAT IS THE VAQUEROS FORMATION OF CALIFORNIA AND IS IT OLIGOCENE?[1]

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ABSTRACT

The Vaqueros formation of the Coast Ranges of California has not been adequately defined as a stratigraphic unit and its early Miocene age is an assumption. Considering that Lyell (1833) specified a type locality for the Miocene, and believing that the Aquitanian stage of Europe should be taken as upper Oligocene, the writer expresses the opinion that the *Turritella inezana* zone, in whole or in part, may prove to be of Oligocene age.

This paper raises issues to be treated in the future in connection with a discussion of "The Oligocene Problem."[3] In the hope that a preliminary statement may provoke helpful criticism, the following two assertions are offered for debate: (1) the Vaqueros formation has not been adequately defined as a stratigraphic unit; and (2) the Miocene age of the Vaqueros formation is an assumption.

The history of this formation need not be considered here, since pertinent reviews will be found in the papers by Louderback (1913),[4] Wiedey (1928), and Loel and Corey (1932). The majority of geologists take the Vaqueros formation as a cartographic and stratigraphic unit, and as a time unit as well, despite the critical remarks by Louderback (1913, p. 192). The correlation table by Loel and Corey shows that the "type Vaqueros" rests upon a thick series of coarse, massive sandstones and conglomerates of Oligocene or Eocene age "with *Pecten sanctaecruzana*[5] fauna at the top." Yet the writer has collected this *Pecten* in abundance from Vaqueros beds 650 feet stratigraphically above the San Lorenzo formation, as mapped, in the Santa Cruz

[1] Read in part before the Society of Economic Paleontologists and Mineralogists, Pacific Section, in Los Angeles, California, November 8, 1934. Manuscript received, December 16, 1934.

[2] Box 1528.

[3] A paper by this title was read before The American Association of Petroleum Geologists, in Los Angeles, California, November 8, 1934, with the permission of the C. R. B. Educational Foundation, Inc., 42 Broadway, New York City, under whose auspices the writer has had the opportunity to investigate Oligocene fossils and strata in western Europe.

[4] Dates in parentheses refer to the bibliographic references at the end of this paper.

[5] This is *Pecten* (*Pecten*) *sanctaecruzensis* Arnold, 1906.

mountains. This species, therefore, does not establish the "Oligocene or Eocene" age of the presumed subjacent beds at the type area of the Vaqueros. In fact, neither the top nor the base of the Vaqueros formation at that locality has been defined satisfactorily in print.

The original definition of the "Vaquero" sandstone by Hamlin (1904) does not precisely locate the boundaries of the Vaqueros formation. The following is quoted from Hamlin:

> In the Salinas Valley the Vaquero sandstone is a well-defined formation. So far as observed in this region it rests unconformably on the Basement complex[6] and on stratified terranes older than the Neocene, being thus in this locality the oldest known member of the Neocene; in other localities Neocene formations are found below the Vaquero sandstone, indicating that it is not the basal member of the Neocene.
>
> The Vaquero formation is a rather coarse, uniformly gray, white or light yellow quartzose sandstone, with an occasional stratum of granitic pebbles. It is of great thickness along the eastern slope of the Santa Lucia Range, especially in Los Vaqueros Valley; hence the designation proposed by the writer for this series of sandstones. In the Mount Diablo Range it appears at a few points beneath later formations. On the summit of the Mount Diablo Range, around the headwaters of Stone Canyon, there is a series of beds beneath the Monterey shale which may be a portion of the Vaquero or may be older. The Stone Canyon coal beds are in this series. . . .

Just what Hamlin had in mind as the Vaqueros is not clear, and neither he nor any other stratigrapher has published a reasonably accurate definition of the top of the Vaqueros formation at its type area. Loel and Corey (p. 116) place the "*Terebra* zone (top sandstone)" as the upper limit of the typical Vaqueros. However, sandstone at the top of the Vaqueros in Reliz canyon and that at the top of the formation in the adjoining Vaqueros canyon do not mark the same stratigraphic horizon. The contact with the superjacent Salinas shale is gradational, and Kleinpell (1933) has stated, in an unpublished manuscript, that in the bed of Reliz Creek, and eastward, dark argillaceous shale appears prominently in the 600 feet of sediments underlying the Salinas-Vaqueros contact. In view of the nature of the contact with the overlying beds, Kleinpell arbitrarily selects as the top of the Vaqueros formation, not at its type area, but in Reliz canyon, the top of the barren sandstone situated immediately below the *Robulus nikobarensis warmani* zonule and 425 feet stratigraphically below the base of the silty shale of the *Siphogenerina hughesi* zone.

To emphasize the actual cartographic usage of the term "Vaqueros," consider published maps and reports. A geologist who found

[6] Any formation bounded below by igneous and metamorphic rocks of unknown age is obviously undefined as a stratigraphic unit, though it may be a cartographic unit. H.G.S.

Turritella inezana Conrad along with *Pecten* (*Lyropecten*) *magnolia* Conrad in a sandstone, delineated that lithologic unit as the Vaqueros formation, taking as the base and the top any two convenient changes in the physical characters of the strata as he observed them locally. But even strata containing other fossils have been called Vaqueros. Many workers, for instance, are aware of the fact that the "Vaqueros" conglomerate mapped by Fairbanks (1904) in the eastern part of the San Luis Obispo folio contains Cretaceous fossils.[7] At one district on the west side of Salinas Valley, English (1919) mapped a sandstone as Vaqueros, but actually it is Santa Margarita, upper Miocene. The use of the word Vaqueros is, in short, indiscriminate, as Louderback (1913) said 22 years ago:

> The term "Vaqueros sandstone" has only a facies value and not a formational one even in the Salinas Valley region, where it was originally applied.

Any field man will admit that what he maps as Vaqueros in one area may not have the same time value as the Vaqueros he maps in another, a truism that applies to all strata that have a wide distribution. The geologist shows on the map certain tangible facts: the unit he delineates is predominantly a sandstone. If it grades into a shale, that is another problem, customarily solved by finding another name for the finer-grained rocks. Widely realized to-day is the fact that the lower part of the Temblor formation, as originally defined by F. M. Anderson (1905, pp. 169–170) at its type area, is the age equivalent of the upper part of the Vaqueros at its type locality. A statement to this effect was published by Kleinpell (1933; 1934-A). The correlation was not convincing to a few stratigraphers, however, until the discovery recently reported upon by L. M. Clark and Alex Clark, in a paper entitled, "The Vaqueros in the Temblor Range," read before The American Association of Petroleum Geologists, Pacific Coast Section, in Los Angeles, November 9, 1934. They found in a lenticular sandstone in the lower part of the type Temblor a number of characteristic Vaqueros mollusks, including *Pecten* (*Lyropecten*) *magnolia* Conrad. Since local sandstone and shale units in California more or less equivalent in time to some part of the type Vaqueros are now being mapped and named, a compromise with the United States Geological Survey terminology[8] may be reached by referring the various formations to the "Vaqueros group."

[7] The Chico (Upper Cretaceous) fossils occur in sandy shales in the vicinity of Alamo and Pilitas creeks, about 200 feet above the granitic rocks.

[8] This is a compromise for many reasons that can not be taken up here. The writer is not in whole-hearted agreement with the nomenclature codified by Ashley *et al.* in their paper on "Classification and Nomenclature of Rock Units," *Bull. Geol. Soc.*

The second assertion presented for debate is that the Miocene age of the Vaqueros formation is an assumption. This is a logical conclusion if it be admitted that the Vaqueros has not been defined adequately as a stratigraphic unit. But even if this is not admitted, and even if the Vaqueros is considered, as defined by custom, to comprise the *Turritella inezana* zone, the Miocene age of this formation does not rest on a sound foundation. This statement is made in full realization of the inadequate original definition by Merriam (1904, p. 380) of the "zone of *Turritella hoffmani*" (a species that is either valid or is a valid subspecies of *inezana*) and that this original usage suggests a biochron rather than a zone in the meaning of the International Geological Congress of Bologna.[9] From the writings of a number of authors one gathers that they considered the *Turritella inezana* zone to be that group of beds identified by an asemblage of such species as *Turritella inezana* Conrad, *Rapana vaquerosensis* (Arnold), *Pecten* (*Lyropecten*) *magnolia* Conrad, and *Scutella vaquerosensis* Kew, and typically exposed as a thickness of 400± feet of strata along the divide between Reliz and Vaqueros canyons. That the Miocene age of these beds and their correlatives is an assumption will be apparent upon reading the following critique, divided for convenience into the topics (1) diastrophic record; (2) evidence from fossil mammals; (3) evidence from the mollusks; (4) evidence from the foraminifers; and (5) the use of the terms "lower Miocene" and "Miocene."

Diastrophic record has been employed to delimit the Vaqueros and to influence acceptance of an early Miocene age for the formation. Loel and Corey (1932, p. 163) may again be regarded as expressing orthodox views, in stating that at the "opening of Vaqueros time . . . the simple features of the Eocene and Oligocene seas . . .

America, Vol. 44 (April 30, 1933), pp. 423–59. A *stage* according to the International Geological Congress (Bologna meeting, 1881; Paris meeting, 1900) is a stratigraphic term. It is neither a cartographic nor a restricted time term, though it involves the idea of time, in the sense that a stage is the rock deposited during a specified time interval, an *age*. A stage is a group of beds constituting a division of the rock column. This division of the rock column is generally based on evolutionary changes of organisms, the customary means of marking geological time. Each stage name is based on rocks at a definite locality; and each name has regional, not inter-regional applicability, according to the Paris congress, though some stage names may have widespread application. Vaughan (1924, p. 682) wrongly interprets the European usage of the word stage. Finally, stage names may be independent of local lithologic units; for example, see Blayac (1930).

[9] For a discussion of zones, the reader is referred to Diener's *Grundzüge der Biostratigraphie* (1925), pp. 215–41, and Arkell's *The Jurassic System in Great Britain* (1933), pp. 1–37. The difference between a zone and a biochron is clear. "Biozone" is a synonym of H. S. Williams' term "biochron." The biochron of *Turritella inezana* can be extended at least to the time represented by the top of the Gould shale, according to R. M. Kleinpell (written communication), who bases the statement on specimens collected by J. Hollister and W. D. Kleinpell.

had just been disrupted by general deformation and uplift." Their view parallels that expressed by Arnold (1909), but the truth of the quoted statement depends solely upon the definition of "Vaqueros." If one considers a district where, during Vaqueros time, only shale was being laid down, would such diastrophism be so pronounced? Do other known facts support the idea of general deformation and uplift? They do not. There are too many sections in California where there is no pronounced break between "typical Vaqueros" and the subjacent beds. The argument, therefore, that the Miocene in California begins with a widespread transgression of the sea is not sound.

Species of fossil mammals have played an important rôle in the age assignment of the Vaqueros formation. Especially cited is the *Merychippus* zone of the Temblor formation of the region north of Coalinga, best known through the memoir by Merriam (1915). A. Morley Davies (1934), noting that the upper beds of theTemblor have yielded a mammalian faunule including a species of *Merychippus*, *Desmostylus*, and others, claims that the Temblor is "definitely high in the Lower or low in the Middle Miocene." That is to say, in terms of the European sequence, the upper beds of the Temblor at that locality in California are either Burdigalian or Helvetian. Where does the *Merychippus* zone come in the Miocene section of California? Although traditionally denominated "Upper Temblor," it is younger than the "button bed," with *Scutella merriami* (Anderson) which was used to define the top of the Temblor formation at its type locality.[10] This means that the zone in question occupies a considerably higher position than has been supposed.

Consider next the evidence afforded by the marine fossil mammals, so well described in the many papers by Reminton Kellogg. *Aulophyseter morricei* Kellogg (1927) was described from the "uppermost fossil horizon of the Temblor formation, on the hill west of Round Mountain" in Kern County, and was assigned to the "Helvetian, Middle Miocene." Micropaleontologists are sure that this Round Mountain locality is higher stratigraphically than the top of the Temblor formation at its type locality. The conclusion based upon the *Merychippus* zone and this species of fossil whale is that both the type Temblor and the type Vaqueros are older than Helvetian. Yet *Cetotherium furlongi* Kellogg (1925) was described from the "Vaqueros formation, Middle Miocene or Helvetian stage." Indeed, the writer has carried on a rather extensive correspondence with Kellogg and he has gained the impression that the fossil pelagic mammals themselves can not yet be taken as precisely dating the Vaqueros formation.

[10] The writer is indebted to R. M. Kleinpell for information to this effect.

Recent publications by Stock (1933) throw light on the age of the beds that underlie at least a part of the Vaqueros formation. The assemblage from the Sespe formation of Las Posas Hills he called "late Oligocene" and the equivalent in time of the fauna from the John Day and upper White River formations. But is the Sespe faunule the time equivalent of the lower marine Vaqueros of California? R. A. Stirton thinks (oral communication) that the Tecuya beds in Kern County (see Stock, 1920) and the upper part of the Sespe formation of South Mountain, Kew Quarry fauna, Ventura County, represent essentially contemporaneous deposits and that both fall within the limits of the *Promerycochoerus* zone of the Monroe Creek and Lower Rosebud formations in Nebraska and South Dakota. Cook and Cook (1933, p. 44) call this zone Oligocene. Moreover, just what do vertebrate paleontologists mean by "Oligocene?" It would seem that many, if not all, take the Aquitanian stage of Europe and its correlatives as upper Oligocene.

The vertebrates help in narrowing down the age possibilities of the Vaqueros formation. They permit the statement that the Vaqueros, as it is loosely defined by custom and practice, is younger than late Eocene, no matter how that word is defined, and older than the Helvetian age of the Miocene. Some part of the Vaqueros, if not all, may be of Aquitanian age.

Now consider the evidence from the molluscan fossils. Loel and Corey (1932, p. 161) state:

> In spite of the close relationship between the Vaqueros and Temblor faunas, there are twice as many living forms in the Temblor as in the Vaqueros.

Moreover, they hold the view that:

> Although the percentage of living species in the Vaqueros fauna corresponds to those given for other Lower Miocene faunas, it is smaller than any reported.

Lyell's original definition of the Miocene takes into account 1,021 species of mollusks, of which 18 per cent are Recent. More modern computations by Peyrot (1932) set the number of species of gastropods and pelecypods in the Burdigalian stage of the Aquitaine basin at 943 as against 717 in the Aquitanian stage. About one-half of the Burdigalian fossils are known from the Aquitanian stage. Peyrot affirmed that the number of species of the Tertiary seas from Aquitanian to and including Tortonian time which have persisted until to-day without appreciable modifications is only 10 per cent. Loel and Corey (1932, p. 154) set the "total number of known Vaqueros

forms (includes Vaqueros-Temblor transition forms)" at 189 or less than one-third the total number from the Aquitanian stage of southern France. They give the percentage of Vaqueros forms which are living as 8.9, a figure lower than Peyrot gives for the species of France and appreciably lower than Dollfus gives for the type Aquitanian. If Loel and Corey relied upon percentages, then why did they not conclude that the Vaqueros was older than Miocene?

Comparison of the Vaqueros mollusks has been made with those from the Anguilla formation of Anguilla Island. This is the formation carrying *Orthaulax aguidillensis* Maury, which Cooke (1921) called questionably upper Oligocene. Vaughan (1924, p. 733) claimed that the Anguilla may be of Burdigalian age, whereas others refer it to the Aquitanian, without direct evidence in any case. Whatever the age of the Anguilla, the fossil mollusks from it, as recorded by Cooke (1919), afford little reason for believing that the Vaqueros and Anguilla formations are contemporaneous.

Indeed, such a well-investigated group as *Turritella* has yet to yield identical species between the Vaqueros and strata in the tropical Americas. Charles W. Merriam informs the writer[11] that:

> Turritellas of the Vaqueros, proper, in so far as I am aware, are all relatives of *T. inezana* Conrad. They appear to me to fall in what I have termed the *T. altilira* Conrad Group. *T. altilira* is a Gatun type: it has many affiliates (varieties and subspecies) in the middle, upper, and probably lower Miocene of Lower California, Tehuantepec, Central America, West Indies, Venezuela, Colombia, Trinidad, Ecuador, and Peru. All of these types inclusive of *T. inezana*, possess what I have called cingulate nuclear ornamentation, which I do not know in any *Turritella* below lower Miocene in America.

At first reading, this seems to be proof that the Vaqueros formation is Miocene, but not so when one recalls that some of the so-called Miocene formations with relatives of *T. inezana* in the tropical Americas may be synchronous with the Aquitanian stage of Europe, or even older.

Pecten, sensu lato, is another intensively studied group of mollusks, and it fails to add decisive data. Qualified paleontologists dismiss as an error of judgment Grant and Gale's (1931) recent synonymizing of *Pecten* (*Lyropecten*) *magnolia* Conrad with a Miocene species from eastern United States. Concerning the pectens, Leo G. Hertlein states:[12]

> *Pecten magnolia* is usually placed in *Lyropecten*, but I suspect it is equally close, if not in fact closer, to one (*Gigantopecten*) of the Mediterranean Mio-

[11] Letter dated October 31, 1934.

[12] Letter to the writer dated November 1, 1934.

cene subgenera. . . . The large, thick-shelled pectens (including the lyropectens) are especially prominent in the lower and middle Miocene of the Mediterranean, Caribbean, and west American regions. . . . As far as I am aware, these large pectens have not been reported in beds considered definitely older than Miocene. Of course, they must have had precursors.[13] In the beds referred to the Tongrian by Roverto, there is a small form which may be a *Lyropecten*; at any rate, it appears to show a resemblance to *P. noduliferus* which occurs in the Indo-Pacific waters. As I recall it, Davies also considers very large pectens as especially characteristic of the post-Oligocene. Those are, of course, generalities and if the Aquitanian (such as of Cossmann and Peyrot) is considered to be Upper Oligocene, then our generalized conclusions would need to be changed.

The data from the pectinids, therefore, are in general agreement with the turritellids, and the objection to the age comparisons in one case applies equally to the other. Actually, the reasoning goes around a circle: "Miocene" beds carry large specimens of *Pecten, sensu lato,* and certain specimens of *Turritella,* hence these mollusks are Miocene. If one questions the basic assumption, or if one calls the Aquitanian and its correlatives upper Oligocene, then the "conclusive proof" of the Miocene age of the Vaqueros formation based on the presence of these fossils vanishes in thin air. Species are often said to be of a given age long after the age of the formation carrying the specimens has been changed. The original sin is a persistent one to the extent of being permanent.

Malacologists have cited the first appearance of genera as evidence that the Aquitanian is Miocene. A. Morley Davies (1929), who takes the Aquitanian as Miocene, stated:

> In Western Europe and the Mediterranean the Miocene fauna consists partly of autochthonous forms evolved from the Oligocene fauna, partly (to a small extent) of a re-infusion of Indo-Pacific forms, and to a striking extent of new forms which come in successive waves from some unknown source or sources, forms which find their nearest representatives in the modern Peruvian fauna.

Judging from his tabulation (page 323), it would be hard to tell whether more new forms were introduced during the Aquitanian, Burdigalian, or Vindobonian. First appearance, like percentages of Recent species, is a dangerous criterion *per se.*

Other malacologists have been influenced in their correlations of

[13] Upon calling Hertlein's attention to the paper by Venzo (1933), describing certain fossils from the Chattian stage of Italy, he commented that the species illustrated as "*Chlamys* (*Aequipecten*) *boucheri* Dollfus" may be an early *Lyropecten.* Cox (*Geol. Mag.*, Vol. LXXI, 1934, p. 339), among others, called attention to Roverto's incorrect age assignments.

Tertiary deposits by supposed faunal breaks. For example, Cooke (1924) affirmed that:

> An important tie point in the correlation of the American and European formations is the faunal break between the Eocene and Oligocene.

Such a statement betrays a lack of appreciation of the actual facts in Europe, for only in local areas is there an appreciable faunal break between the Eocene and Oligocene. The species from the upper Eocene Barton clay of Barton, England, are closely related to the lower Tongrian ones from Belgium, Germany, and England. The "great faunal break" at the close of the Oligocene is a myth, both in Europe and America. The difficulty, moreover, of separating the Cretaceous from the Tertiary is classic. How to distinguish the Miocene from the Pliocene or how to divide the Pliocene from the Pleistocene have never been stated to universal satisfaction.

Evidence from the *Foraminifera* regarding the age of the Vaqueros formation is no more or no less convincing than in the case of the other phyla. The *Lepidocyclina* recently recorded from the Vaqueros of California by Taliaferro and Schenck (1933) appears most nearly related to a species from the Oligocene of Antigua, namely, *L. forresti* Vaughan, but further comment on this subject is withheld pending the completion of current investigations.[14] R. M. Kleinpell believes that the smaller foraminifers from beds corresponding more or less to the limits of the Vaqueros formation, as currently defined, have their closest affinities with the much-disputed Eocene-Oligocene-Miocene faunule from Venezuela and Ecuador, described and discussed in papers by Galloway and Morey (1929), Cushman (1929), Dorr (1933), and Kleinpell (1934-B). Some of the discrepancies of this interregional correlation may be explained by the following statement by Hollis D. Hedberg (oral communication).

> Some of the recent speculation on the age of the faunule described by Cushman from Aguide, District of Zamora, State of Falcon, Venezuela, seems rather futile when it is considered that this collection represents a single sample and a single horizon in a foraminiferal marl many thousands of feet thick. Work by paleontologists acquainted with this region shows that the bulk of species present at the Aguide horizon range through great thicknesses of these so-called "Agua Salada clays," which constitute a lithologic facies

[14] The final report on the *Lepidocyclina* from California will include, among other discussions, notes on the records of *Nephrolepidina*, *Eulepidina*, *Discocyclina*, et cetera, from the Eocene of northern Africa. The most recent notes on this subject are by Bourcart and David (1933) and by Flandrin (1934). *Lepidocyclina* in the Eocene of Africa may influence E. W. Berry (*Amer. Jour. Sci.*, 5 ser., Vol. 13 (March, 1927), pp. 252–56) to change his views on the Oligocene, and will cause orbitoid specialists to revise their opinions concerning the birthplace of this genus.

unit into which merge a group of formations with almost the collective time value of a Tertiary epoch. Only as a result of very detailed work has this unit been zoned stratigraphically. The diversity of opinion represented by the several long-range correlations of the Aguide horizon does not seem to me to be merely a matter of nomenclature; it is rather due to the attempt to stretch the meager and inadequate data supplied by one sample into the basis for an inter-continental correlation, to lack of familiarity on the part of the writers with the local (Venezuelan) stratigraphy, and finally, to neglect of the fact that, within a limited stratigraphic range, equivalence of facies may be as big a factor as age equivalence in producing a considerable percentage of identical species in two assemblages.

The *Foraminifera* from Kleinpell's Zemorrian stage (including, among other things, the *Turritella inezana* zone) therefore harmonize with the contention that the Miocene age of the Vaqueros formation of the geological cartographer is not established beyond a shadow of doubt.

Several years ago, before questioning the Miocene age of the Vaqueros, Boris Laiming informed the writer that when comparing specimens of smaller foraminifers from the lower member of the Rincon shale, which lies immediately above "Vaqueros sandstone" in Ventura County, California, with specimens from Europe, he found some similarities with Oligocene species.[15] More recently he wrote as follows.[16]

Some species are common to both the lower Rincon shale and material from Hildesheimer Wald bei Dieckhalzen, Hannover province, Germany, considered upper Oligocene by Dr. A. Franke. These species were: *Spiroplectammina gracilis*, *Marginulina dubia*, *Sphaeroidina* cf. *variabilis*, and *Angulogerina occidentalis*. Species related to *Guttulina hughesi*, *Cibicides americanus*, *Anomalina glabrata*, and *Cibicides floridanus* were also noted in that Oligocene material from Germany. To date, however, my studies of the European Oligocene are insufficient to warrant any definite conclusions as to correlations with the California section.

One does not have to look far for a reasonable explanation for the origin of the belief that the Vaqueros is Miocene. One needs only consider the history of the study of the Tertiary of the Pacific Slope of North America. The expeditions sent out by the War Department to survey proposed railroad routes were made in 1853–1854, just about the time that von Beyrich was making his formal announcements regarding the newly-coined term "Oligocene." The coincidence of dates means that American paleontologists had not at that time come to realize that the species they were calling Miocene might better be

[15] The *Foraminifera* from the Rincon shale were described by Cushman and Laiming (1931).

[16] In a letter to the writer dated November 2, 1934.

known as Oligocene. Conrad (1857) in the report carrying the original description of *Pecten magnolia* treated as Miocene certain species, such as *Turritella variata*, coming from horizons stratigraphically below the Vaqueros sandstone; nevertheless, he commented as follows.

> In referring these fossils to the Miocene group, it is not with the understanding that they are exactly parallel with European or even Virginian Miocene strata, but they are unquestionably situated between the Eocene and newer Pliocene, containing no species analogous to the former, which is admirably characterized in California by its general forms, and even by a few well known Claiborne species.

Conrad himself was not positive regarding the exact age of the species now taken as index fossils of the Vaqueros. Later authors found it less embarrassing to assert simply that the Vaqueros is early Miocene than to admit that its age is not settled beyond all doubt.

A second explanation is that succession of formations has been a more potent factor in inter-regional correlations than comparisons of faunules. The relative positions of the faunal zones of the Pacific Slope Tertiary are reasonably accurate, but precise comparisons with Europe have been made chiefly on paper.[17] For example, since there is a formation in California that occupies approximately the place that the Aquitanian stage occupies in Europe—provided all other correlations are exact—that formation in California is of Aquitanian age.

The fifth point pertinent to the critique is to consider what is meant by the terms "lower Miocene" and "Miocene"—words used in many senses. Kellogg (1922) is among those who call the Burdigalian and Langhian (see Kellogg, 1931) stages "lower Miocene," and who treat the Aquitanian as upper Oligocene. Some malacologists oppose the specialist on the vertebrates by affirming that the Aquitanian is lower Miocene, but the case is not proved. Those who advocate the Aquitanian age of the Vaqueros, as for instance G. D. Hanna (1932), can not consistently argue that it is "certainly Miocene" simply on that basis. The Miocene is no better defined in Europe than it is in the Americas. Neither from current literature nor from present-day investigators in western Europe could the writer find confirmation of the assertion by Vaughan (1933, p. 925) that

> in Europe it appears that it has been possible to reach consensus of opinion regarding a boundary between the Oligocene and Miocene.[18]

[17] The latest of these comparisons are those prepared by Shimer (1934).

[18] Among the numerous papers dealing with the boundary between the Miocene and Oligocene is that by Oppenheim (1913). That the Aquitanian is considered as

What is "Miocene"? The original definition by Lyell (1833, pp. 54–55) reads:

> The next antecedent tertiary epoch we shall name Miocene, from μειων, minor, and καινος, recens, a minority only of fossil shells imbedded in the formations of this period, being of recent species. The total number of Miocene shells, referred to in the annexed tables, amounts to 1021, of which 176 only are recent, being in the proportion of rather less than 18 in 100. Of species common to this period, and to the two divisions of the Pliocene epoch before alluded to, there are 196, whereof 114 are living, and the remaining 82 extinct, or only known as fossil.
>
> As there are a certain number of fossil species which are characteristic of the Pliocene strata before described, so also there are many shells exclusively confined to the Miocene period. We have already stated, that in Touraine and in the South of France near Bordeaux, in Piedmont, in the basin of Vienna, and other localities, these Miocene formations are largely developed, and their relative position has been shown in diagrams Nos. 3 and 4, letter *e*, Chapter II.

Vaughan (1924, p. 703) interprets this freely, concluding that:

> It seems that the "Faluns of Touraine" are *par excellence* type Miocene.

The "faluns de la Touraine" are younger than Burdigalian, that is, they are Helvetian, according to Peyrot (1932, p. 491). This age is significant in view of the quotation from Lyell given below. Authors have overlooked the definite selection of a type locality for the Miocene by Lyell (1833) in the preface (pages xii–xiii) of his third volume of the "Principles" above referred to. This is the passage:

> I had now fully decided on attempting to establish four sub-divisions of the great tertiary epoch, the same which are fully illustrated in the present work. I considered the basin of Paris and London to be the type of the first division; the beds of the Superga, of the second; the Subapennine strata of northern Italy, of the third; and Ischia and the Val di Noto, of the fourth.

Lyell's table on page 61 and tables I and II on pages 386 and 389–90 show that these four subdivisions are the ones named Eocene, Miocene, Older Pliocene, and Newer Pliocene. Furthermore (page 211), discussing the Superga locality, the author stated:

> The late Signor Bonelli of Turin was the first who remarked that the tertiary shells found in the green sand and marl of the Superga near Turin differed, as a group, from those generally characteristic of the Subapennine beds. The same naturalist had also observed, that many of the species peculiar to the Superga were identical with those occurring near Bordeaux and Dax.

Oligocene by some modern writers can be verified by consulting such papers as those by Baumberger (1934), Gregory and Barrett (1931, p. 203), Kautsky (1925), Linstrow (1922), Richter (1934), Viret (1929), and others too many to mention here. More may do so when they realize that the Miocene has a designated type locality.

To designate the Miocene beds of the Superga district as type Miocene is imperative. The fossils that constitute *"la fameuse faune de la Superga"* are listed by Sacco (1905), but attention is directed also to the correlation table in Kayser (1924). The age of the beds is given as Helvetian, the same as the "faluns de la Touraine." The type Miocene is therefore interpreted to be no older than Burdigalian.[19] The lowering of the limit of the Miocene so as to include the Aquitanian seems unjustified. Moreover, the hypothesis that the type Aquitanian synchronizes with the type Chattian, in whole or in part, needs serious consideration. When the matter was mentioned to Professor G. Stafanini, of the University of Pisa, he replied as follows,[20] freely translated.

The classic outcrops at Montecchio Maggiore and of Sangonini are of the greatest interest, and if you are partisan of the Aquitanian equalling Upper Oligocene you will find in the Trentino section,[21] which one of my students has just studied, some arguments in favor of your thesis, for the passage between the Chattian and Aquitanian is so gradual that the division of the terrain is difficult.

Considering the original definition of the Miocene and the evidence from stratigraphy and paleontology, therefore, the writer of this note believes that the Aquitanian stage of the European stratigraphic column should be placed in the Oligocene.

A name in itself means little. A name standing for a concept means much. If the concept is to be precise, the name must have an exact definition. It matters little perhaps if the Vaqueros (meaning the *Turritella inezana* zone) is called upper Oligocene or lower Miocene, so far as the sequence of strata and local faunal zones is concerned, but if other aims of research are to work out the phylogenetic relations of species, correlate geologic formations in widely separated areas, synchronize terrestrial and marine beds, and attempt to understand the geographic distribution of organisms, to say nothing of an attempt to understand the sequence of physical events with any degree of accuracy, the same term—whether it be in stratigraphic or zoölogic nomenclature—must mean the same thing everywhere. Whether the

[19] Haug (*Traité de Géologie*, II, Fasc. 3, pp. 1640–41) points out that the presence of the Aquitanian on the two flanks of the anticline that make up the hills near Turin is doubtful and that the basal beds are Burdigalian. It may be mentioned also that Lyell himself did not help to simplify the problem of the classification of the Miocene by his later writings, such as his *Manual of Elementary Geology* (1858).

[20] In a letter to the writer dated August 9, 1934.

[21] Consult the papers by Oppenheim (1913), Fabiani (1922), and Venzo (1933). The latter (pp. 212–13) states that the faunule (with *Dosinia exoleta*) described by Vinassa de Regny (*Boll. Soc. Geol. Ital.*, Anno XV, Vol. 15 (1896), pp. 192–213) is Oligocene. H.G.S.

restricted Vaqueros is Oligocene—which it probably is—or Miocene can not be asserted without qualifications, because too many unsettled questions must be answered, and not the least important is to decide on what criteria should be accepted as marking a new period. More practical than drawing arbitrary lines is the establishment, by the paleontologist, of a sequence of faunal zones, each named, as a zone should be, according to its characteristic fossil, and the mapping, by the geological cartographer, of the physical rock units as he finds them in the field in local districts. No accurate correlations will be possible until time and rock units are separated in the investigator's mind and words, and the founding of locally named stages is a rational way to establish a satisfactory classification of the Tertiary rocks of the Pacific Slope of North America.

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ANTICLINES BETWEEN HIAWATHA GAS FIELD AND BAGGS, WYOMING[1]

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ABSTRACT

Salt Lake City, Utah, and Rock Springs, Wyoming, receive a considerable part of their supply of natural gas from the Eocene Wasatch formation, in the Hiawatha gas field, which spans the Wyoming-Colorado boundary line south of Rock Springs. Supplemental supplies of gas may be expected from a series of small anticlines that extend eastward from the Hiawatha field to the town of Baggs, Wyoming. Five of these anticlines are described here. The stratigraphy and regional structure are discussed briefly, and the accompanying map shows the areal geology and structural relations of the folds and faults.

INTRODUCTION

Considerable quantities of natural gas are being produced from the Wasatch formation, of Eocene age, in the Hiawatha gas field, which lies partly in Moffat County, Colorado, and partly in Sweetwater County, Wyoming. This gas is piped about 40 miles northwest to supplement the flow of gas from the Baxter Basin field. A pipe line from the Baxter Basin field to Salt Lake City, by way of Rock Springs, Wyoming, insures a market for the gas from both fields. Auxiliary supplies of gas may be expected from a series of rather small anticlines that extends eastward from the Hiawatha gas field about 35 miles along the Colorado-Wyoming boundary to the town of Baggs, in the southwestern part of Carbon County, Wyoming. Two of the anticlines in this strip along the State line—the Powder Wash anticline, in the northern part of T. 11 N., R. 97 W., Moffat County, Colorado, and the Baggs anticline, in the southeastern part of T. 13 N., R. 92 W., Carbon County, Wyoming, have been drilled, and on each flows of gas were struck. At a depth of 2,150 feet the well drilled on the Powder Wash anticline is reported to have struck a flow of gas gaged at a little more than 34 million cubic feet a day. A perceptible flow of gas was struck at 750 feet in the first well drilled on the Baggs anticline.

In the summer of 1933 this strip of country between the Hiawatha gas field and the town of Baggs was mapped by W. H. Bradley and

[1] Published by permission of the director of the United States Geological Survey. Manuscript received, February 1, 1935.

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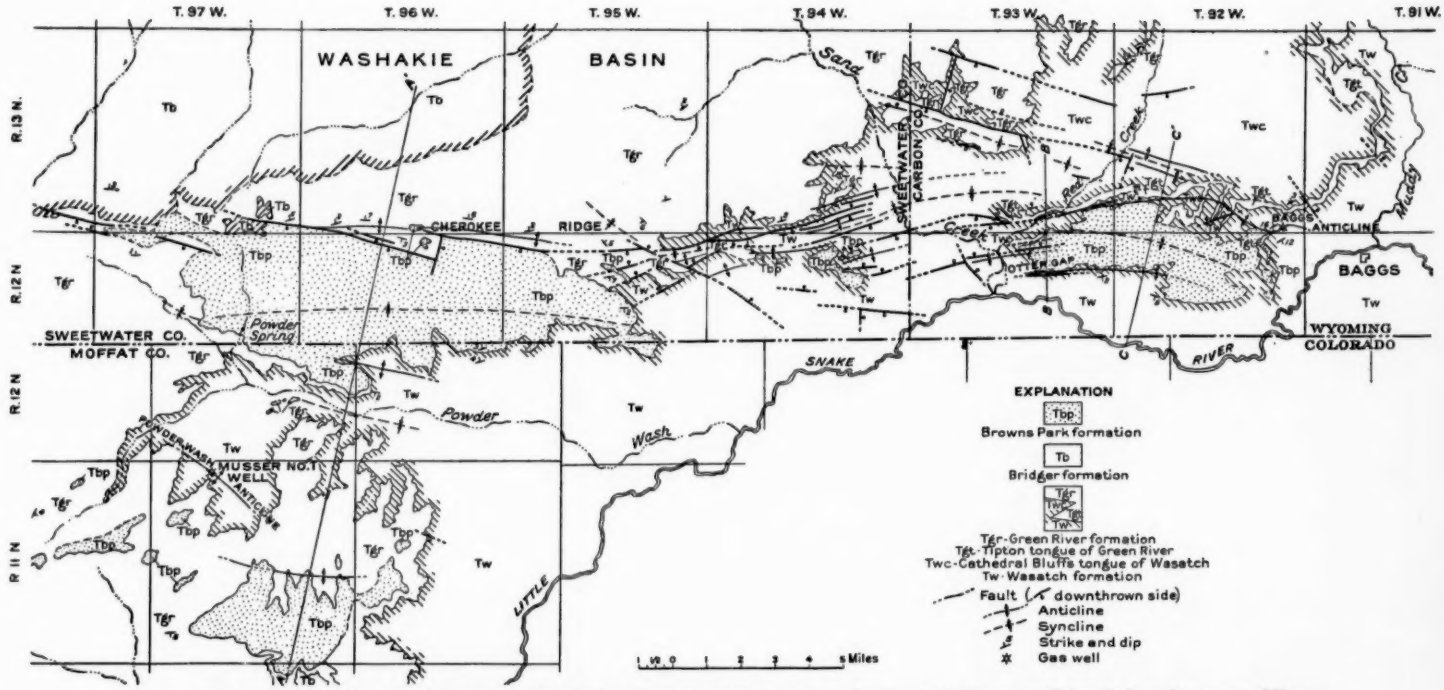

FIG. 1.—Geologic map showing the distribution of the folds and faults in the Tertiary rocks along the Wyoming-Colorado boundary west of Baggs.

Frank S. Parker, geologists of the United States Geological Survey. The map accompanying this report (Fig. 1) is based on that field work. Although this area was mapped on plane tables with telescopic alidades, the examination was in reality a reconnaissance, as the scale used was 4 miles to the inch. Accordingly, the positions of the anticlinal axes and the structural relief across certain sections of the folds can be given only approximately. However, this paper may serve as a useful guide in selecting specific areas for more detailed work.

ROCKS EXPOSED IN REGION

All the exposed rocks are of Tertiary age. The Eocene rock units differentiated on the accompanying map are, in order upward, the Wasatch, Green River, and Bridger formations. The upper part of the Wasatch formation makes a tongue, known as the "Cathedral Bluffs tongue," which in the eastern part of the area separates the Tipton tongue of the Green River formation from the main body of the formation. The Tipton tongue of the Green River formation thins southward and westward and loses its identity in the vicinity of Sand Creek, about 11 miles west of Baggs. Overlying the Eocene rocks with angular unconformity is the Browns Park formation, of late Miocene or early Pliocene age.

The Wasatch and Bridger formations are dominantly of fluviatile origin, though the Bridger contains an abundance of volcanic ash and a small quantity of lake beds. The Green River formation which, farther north, along the west side of Washakie Basin, Contains oil shale, was deposited in a large lake.

The Wasatch formation consists chiefly of drab or color-banded mudstone. It also contains sandstone, but the distribution is rather irregular. In large areas the Wasatch contains relatively few muddy sandstone layers and rare thick stubby lenses, but locally sandstone is abundant. In the vicinity of Otter Gap, on Sand Creek, and thence westward into R. 95 W., the Wasatch contains many thick sandstone beds, some of which are coarse grained and nearly pure white. The Cathedral Bluffs tongue of the Wasatch is characterized by the scarcity of sandstone and the intense red color of the mudstone. In T. 14 N., R. 93 W., this tongue is about 400 feet thick.

Buff-to-gray marlstone, calcareous shale, and light yellowish brown sandstone beds make up the bulk of the Green River formation in this area. The Tipton tongue of the Green River formation is characterized by light-to-dark brown papery shale that is more or less carbonaceous. In the northeastern part of the area the Tipton is about 100 feet thick.

The Bridger formation, which conformably overlies the Green River, is made up of gray mudstone and volcanic ash with lenticular beds of poorly sorted sandstone.

The Browns Park formation has a thick basal conglomerate, above which is about 75 feet of fairly evenly bedded sandy and tuffaceous mudstone and sandstone, which in turn is overlain by a thick series of white, highly cross-bedded sandstone and white tuff. At the top of this sandstone unit are beds of dense quartzite.

STRUCTURAL FEATURES

The belt of folds and faults shown on this map forms the south side of a large but shallow depression known as "Washakie Basin." This structural belt or zone, together with the subsidiary folds in the vicinity of Powder Wash, separates Washakie Basin from Sand Wash Basin, a similar though considerably smaller structural basin on the south. In a broad way this belt appears to be an eastward extension of the structural lines in the Hiawatha gas field. After the Eocene rocks were warped and faulted, the region was planed off into a smooth pediment by streams flowing out from the Uinta Mountains and Sierra Madre, to the south and southeast. Upon this erosion surface the Browns Park formation was deposited. Subsequent earth movements not only warped and faulted this erosion surface and the Browns Park beds, but also accentuated certain of the structural features in the underlying rocks. Consequently, folds in the Browns Park formation in some places nearly coincide with the folds in the underlying older Tertiary formations, but in other places synclines in the Browns Park overlie anticlines in the older rocks. As the gas in the Hiawatha field and that found in the Powder Wash and Baggs anticlines comes from the Wasatch formation, only anticlines in that formation or the conformably overlying Green River formation will be considered here.

The largest anticline in the belt is the faulted anticline along the crest of Cherokee Ridge, approximately on the line between Ts. 12 and 13 N., Rs. 95 and 96 W., Sweetwater County, Wyoming. Beds near the middle or lower part of the Green River formation are exposed at the crest and on the north flank of this fold, but a little way south of the axis the quartzite and white sandstone of the Browns Park formation are faulted down against the Green River. On the north side the beds dip 2°–7° N., into Washakie Basin; on the south side they dip about 3° S., except close to the faults, where they are dragged down into steeper dips. Because of the angular unconformity between the Browns Park formation and the older Tertiary rocks it

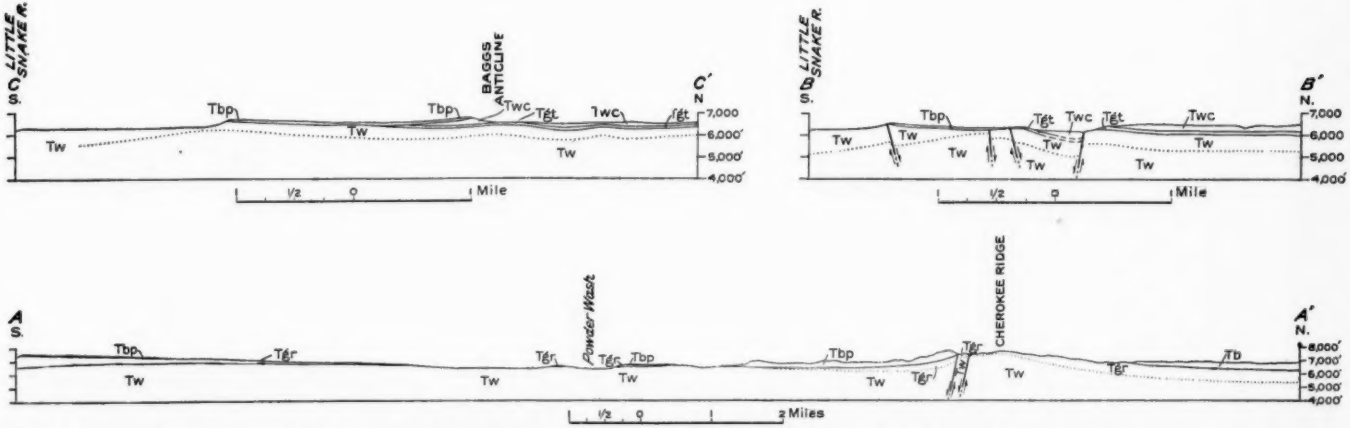

FIG. 2.—Structure sections across the belt of folded and faulted rocks shown in Fig. 1. The dotted line in each section is a hypothetical stratum in the Wasatch introduced to depict the inferred attitude of the beds below the surface.

is impossible to determine the attitude of the Green River formation south of the main Cherokee Ridge fault, but its approximate attitude may be inferred from the exposures both east and west of the area covered by the Browns Park formation. Structure section *A–A′* (Fig. 2) shows the probable relations of the beds on each side of the Cherokee Ridge anticline. If this interpretation is correct, the structural relief along this section may be as much as 1,000 feet. The amount of closure on this fold is unknown, but the fold apparently plunges westward, as in that direction the altitude of the ridge decreases, yet successively higher beds of the Green River formation come in at the crest of the fold until in Sec. 35, T. 13 N., R. 97 W., the overlying Bridger formation is at the crest. A small syncline, whose axis extends northwestward through Sec. 3, T. 12 N., R. 95 W., appears to close the fold at the east end. The main Cherokee Ridge fault cuts the axis of the anticline in Sec. 34, T. 13 N., R. 96 W., but the effect of this fault is not known. The Cherokee Ridge anticline is closely similar to the anticlines that extend southeastward along the ridge that forms the south side of Sand Wash Basin, in Moffat County, Colorado, south of the area discussed here.

A few miles southeast of the Powder Wash anticline is a broad low anticline, similar to the Powder Wash fold, whose axis extends approximately east-west through the middle of T. 11 N., R. 97 W., Moffat County, Colorado. Beds about the middle of the Green River formation are exposed at its crest and on the north flank, but on the south flank the Green River beds dip southward and pass below the basal conglomerate of the Browns Park formation, which there dips a little less than 2° N. These relations are shown in structure section *A–A′* (Fig. 2). The west end of this broad arch has at least a small closure by reason of the low saddle that separates it from the Powder Wash anticline. Whether or not this arch has any closure at the east end is unknown.

In the eastern part of the area the axis of a small anticline extends from the center of T. 12 N., R. 92 W., Carbon County, Wyoming, westward nearly to the center of T. 12 N., R. 93 W., where it narrows down and apparently merges into the drag along a fault that is nearly parallel to its axis. Beds a few hundred feet below the top of the Wasatch formation are exposed at the crest and in the south flank. North of the axis these beds pass under the Browns Park formation with only a small angular discordance. The basal beds of the Browns Park here contain only thin pebble layers that are overlain by more or less sandy mudstone and fissile shale, resembling in many ways parts of the Green River formation. As shown in structure section *B–B′*

(Fig. 2), this anticline has a maximum structural relief of about 400 feet between its crest and the troughs of the adjacent synclines. The fold apparently has a moderate closure at the west end, but the structure at the east end is concealed and unknown.

Approximately 4 miles north of this anticline and nearly parallel with it is the westward extension of the Baggs anticline. This fold, which is narrow and has only a small structural relief, exposes along its crest the Wasatch formation, the Tipton tongue of the Green River formation, and the Cathedral Bluffs tongue of the Wasatch. Its south flank is in part concealed beneath the Browns Park formation. It apparently dies out westward against a fault that is nearly parallel with its axis. A small "high" on the east end of this anticline was tested in 1930 by two wells. The first well is reported to have struck, at about 750 feet, a small flow of gas. The second well is reported to have struck showings of gas at several horizons. Both wells were drilled a little deeper and are now closed.

At Otter Gap, in Secs. 3 and 4, T. 12 N., R. 93 W., there is a small faulted anticline in the Wasatch formation whose axis trends a little south of west. This fold, which has a moderate structural relief, plunges westward and ends against a fault that strikes nearly at right angles to it. Eastward the anticline passes beneath a syncline in the Browns Park formation and apparently merges into the north flank of the anticline in the Wasatch beds, whose axis passes through the middle of T. 12 N., Rs. 92 and 93 W.

Most of the other anticlines shown on the map are small, several of them being mere wrinkles in the beds dropped down between two nearly parallel normal faults.

The faults of this belt fall into two broad groups according to their general direction of strike. The faults of the dominant group strike generally westward; those of the other group strike more nearly northward or northwestward. The faults of the first group are apparently older, as they are cut by faults of the second group. Moreover, the faults of the second group cut beds of the Browns Park formation, whereas the other faults in most places do not. However, some of the larger east-west faults were apparently active during the second stage of faulting, because locally, as along Cherokee Ridge, they cut the Browns Park formation. The fault system in this belt is surely more complex than is indicated by the map, but owing to the lack of exposures and the rapidity of the field work many faults were not mapped, and other short faults were not correlated and connected, as they probably could be with more detailed work.

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GRETA OIL FIELD, REFUGIO COUNTY, TEXAS[1]

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ABSTRACT

Greta oil field, in the north-central part of Refugio County, was discovered by George E. Smith *et al.*, May 5, 1933.

The field is in the shape of an irregular elongate oval measuring approximately 4 by 2.5 miles with its major axis extending N. 22.5° E.

The structure is almost flat on top with steep dips in the beds beginning at the periphery and extending in northeasterly, southeasterly, and southwesterly directions. There is the suggestion of a fault along the northwest side of the field.

The three pay horizons are the Catahoula, or 3,500-foot sand, the *Heterostegina*, or 4,400-foot ("Greta") sand, and the Frio, or 5,900-foot sand.

At the end of 1934 there had been completed 186 oil wells with a total cumulative production of more than 5 million barrels.

INTRODUCTION

Location.—The Greta oil field is located approximately 9 miles northeast of the town of Refugio in the north-central portion of Refugio County, Texas. Federal Highway 77 traverses the area in a northeasterly-southwesterly direction and divides the field into two almost equal parts. Four miles southwest of Greta is the Fox field and approximately 12 miles northeast lie the O'Connor and McFaddin fields. These four oil fields lie almost in a straight line extending N. 45° E. The location of Greta oil field and its relation to surrounding areas is shown by Figure 1.

Physiography.—The average elevation in the field is 65 feet. The topography at Greta, like that of most areas of the Gulf Coastal Plain, is almost flat. The low flat coastal plain dips southeastward at a rate averaging less than 5 feet per mile and merges with the coastal marshes or terminates as bluffs along the coast line. No topographic suggestion is given of an oil field; the only relief in the vicinity lies 2 miles north of the field where a few low hills and sand dunes are found.

History.—The discovery well, George E. Smith *et al.* O'Brien No. 1, was completed May 5, 1933, producing from a *Heterostegina* zone sand of the Middle Oligocene at a total depth of 4,403 feet. Initial

[1] Manuscript received, February 4, 1935.

[2] Stamey, Easton, Montgomery, and Carey, geologists and paleontologists, 1307 Esperson Building.

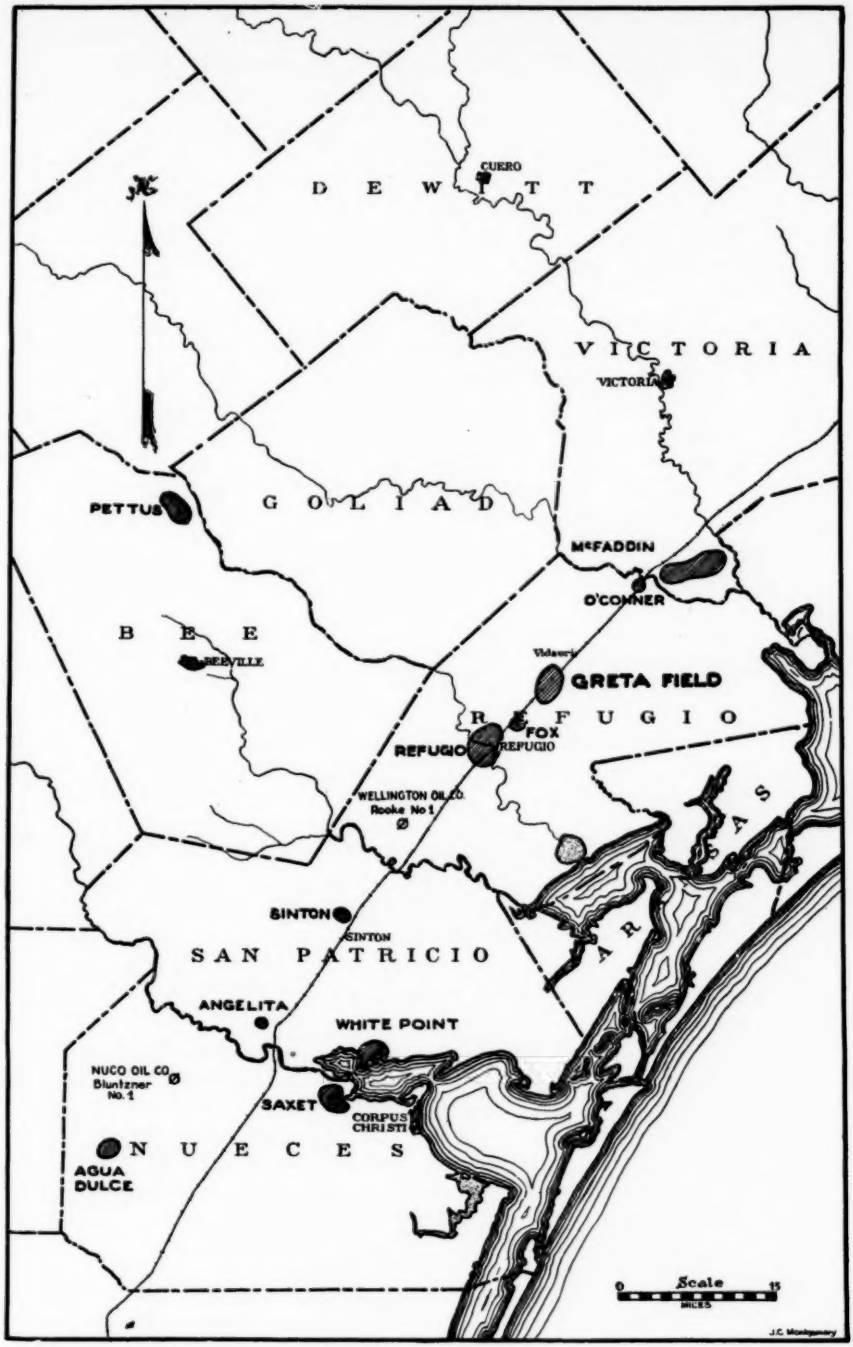

FIG. 1.—Map showing location of Greta oil field and its relation to surrounding areas.

production was 525 barrels (estimated) per day, through a ¼-inch choke with a tubing pressure of 525 pounds per square inch.

In the discovery well the drillers had penetrated the greater portion of the pay horizon, which they logged as "hard sandy lime," before they began coring. As a result only the last 9 feet of the total 70 feet of pay strata was actually cored and subsequently drill-stem tested.

This well, located in the southern portion of a block of approximately 1,400 acres, leased jointly from J. M. O'Brien and his son, J. J. O'Brien, was strictly a wildcat location based by the operators on no geology other than its position with respect to the Refugio, Fox, O'Connor, and McFaddin fields. Prior to the discovery of oil the well created no unusual interest among oil-producing companies, despite the fact that earlier regional investigations of the surface beds by Kenneth D. Owens,[3] working independently, and others had revealed a number of favorable regional, though not local, indications. There was no sale of a portion of the acreage to aid in defraying the drilling costs, a practice widely used in later wildcat operations in southwest Texas. The only assistance from any company was fuel supplied without cost by the United Gas Company, which for several years prior to that time, following a comprehensive study of the surface beds in this region, had acquired large holdings in the area and was obtaining production from a portion of its properties in the near-by Fox field.

The advent of the discovery was the signal for an intensive leasing campaign by numerous companies and individuals. Principal leaseholders in the field at present are the United Production Company, Atlantic Oil Company, Stanolind Oil and Gas Company, Humble Oil and Refining Company, E. M. Jones, Hewitt and Daugherty, and the Floboots Corporation. Several new wells were started within a very short time; the second well to reach completion was the Southwest Oil Corporation's J. M. O'Brien No. 1, which was closely followed by the Alamo Drilling Company's J. M. O'Brien No. 1, south and west, respectively, from the discovery well.

Following these wells development was rapid and within 5 months the field was defined around most of its periphery. Up to the end of 1934, 210 wells were drilled, of which 186 were oil producers, 6 gas wells, 7 blow-outs, and 11 dry holes. Production to that date totaled approximately 5,125,054 barrels. Figure 2, a map of the field, shows the location of these wells, to some of which further reference will be made.

[3] Kenneth D. Owen, geologist, E. DeGolyer, Houston, Texas.

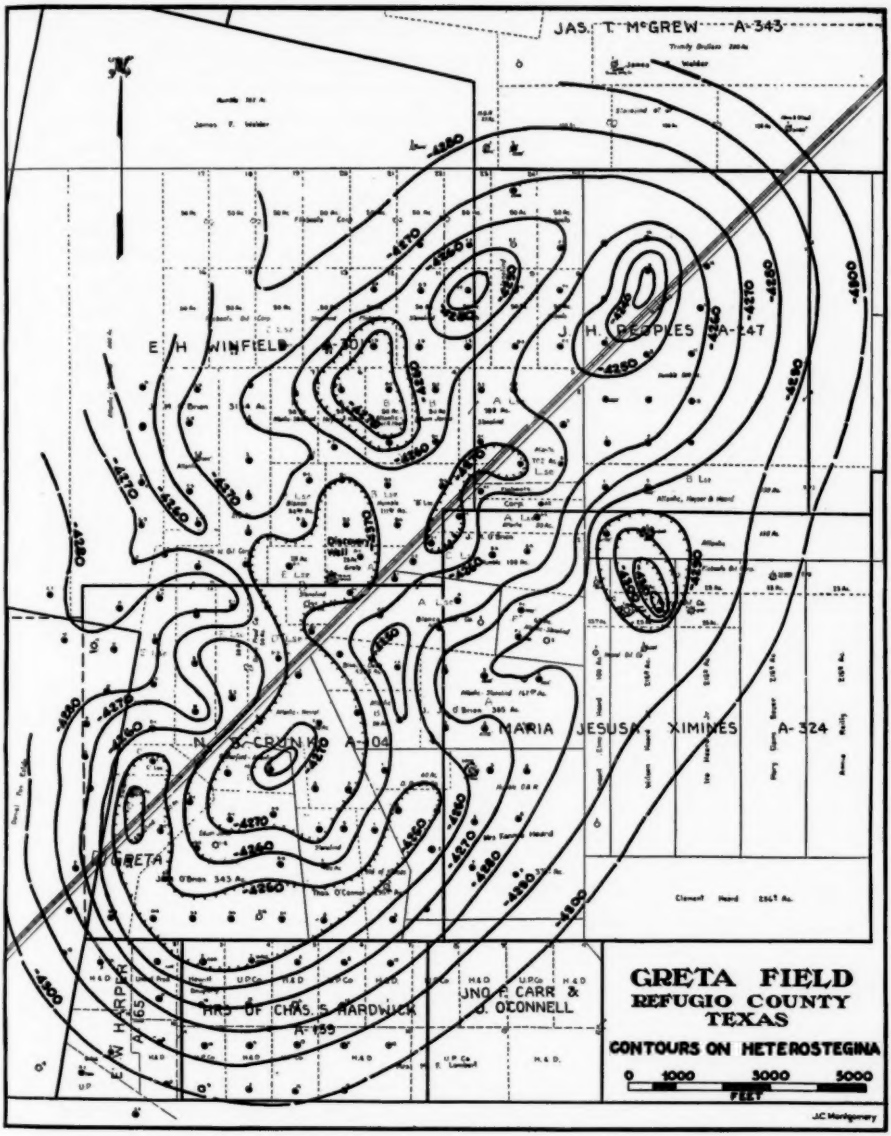

FIG. 2.—Map of Greta field showing contours on *Heterostegina*.

SURFACE GEOLOGY

The Beaumont clay covering the field is exceedingly thin, in few places more than a few feet in thickness. In many places the underlying Lissie formation has been encountered while digging slush pits. In various portions of the field, particularly on the north, are areas covered by several feet of loose sands, but a close examination at these spots by the senior writer leads to the belief that these sands are aeolian deposits. With the exception of the southwest quadrant, which is covered by a thick mass of scrub oaks, the field is a bare prairie. These oaks, whose roots are in sand, are the only visible indication of the near presence of the underlying Lissie sand. Boring by hand auger shows a thinning of the Beaumont beds immediately above the structure.

North of the field and extending for several miles in a direction perpendicular to the coast line is a very pronounced line of topographic sand mounds or dunes interspersed with numerous depressions, some of which form small ponds in wet weather; and on the northwest are several permanent, but shallow lakes. These sand hills and lakes suggest to the writers the presence of an old river bed, but give no indication as to the presence of the near-by oil field.

STRATIGRAPHY

Lissie-Goliad.—Beneath the Beaumont clays are encountered the Lissie sands, which have a gradual and uniform dip toward the southeast of approximately 10 feet per mile. These beds consist largely of sands interspersed with a few thin sections of clays and carry numerous nodules of iron and manganese. The Lissie sands can not readily be differentiated from the underlying Goliad beds and the point of contact between the two formations is not known. At Greta the base of the Goliad is found at a drilling depth of approximately 1,300 feet. Both the Lissie and the Goliad sands carry fresh water suitable for boiler use. Figure 3 shows the generalized geologic section of this area.

Lagarto-Oakville.—The Lagarto formation underlying the Goliad is composed essentially of green clays with a few sands which are mostly lenticular and do not show a uniform dip across the field. One sand at approximately 1,700 feet was found charged with a high gas pressure.

The contact of the Lagarto and the Oakville beds has not been definitely determined. A lithologic break at approximately 1,900 feet has sometimes been suggested as the top of the Oakville, but such a classification is open to debate. Below this depth the beds consist of gray, pale green, purple, red, and brown shales, with some thin sands.

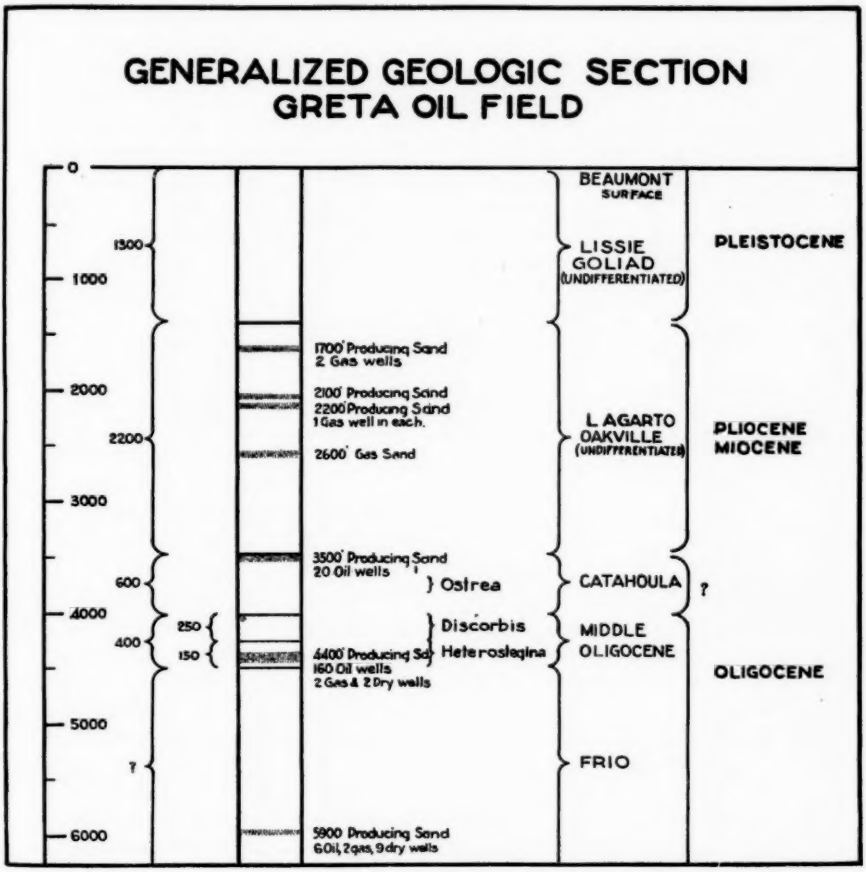

FIG. 3.—Generalized geologic section of Greta field area.

At approximately 2,100, 2,200, and 2,600 feet, thin sands of this section are also found to be highly charged with gas. The field's first blowout came from the 2,200-foot sand encountered in the Nesral Oil Company's Ira Heard No. 1; the second occurred in the Greta Oil Company's J. M. O'Brien No. 2, the gas coming from a point of undetermined depth, but either from the 2,200-foot sand or from the 2,600-foot sand.

Catahoula.—The Catahoula, lying conformably under the Oakville, at an approximate drilling depth of 3,460 feet, is marked by an increase in volcanic ash content and the presence of fresh volcanic glass. Several beds of vari-colored clays lie in the top of the Catahoula, but from this point downward are sands, sandy shales, and volcanic ash bearing the characteristic green color peculiar to these beds. In some places these sands are porous; in others the pore spaces have been completely filled by evenly diffused, fine shale particles and volcanic ash. Some portions of the Catahoula section show traces and small showings of oil, but only on the southeast edge of the field has accumulation sufficient for production been found.

The first dependable paleontologic marker is found near the base of the Catahoula at an average depth of 3,860 feet, where a bed of *Ostrea* is found. The freshly broken shell fragments recovered with cuttings are distinctly different from those reworked *Ostrea* fragments found at higher levels. In the extreme base of the Catahoula occurs a bed of lignite which lies only a few feet above the top of the Middle Oligocene.

Discorbis zone.—At 4,060–4,090 feet the topmost member of the Middle Oligocene, the *Discorbis* zone (marked by *Discorbis* cf. *D. vilardeboana*), is encountered. The top of the *Discorbis* zone at Greta could be determined with fair accuracy without the use of paleontology, provided adequate cores were available, since the distinction between the green, arenaceous, Catahoula materials and the underlying dark gray, dull, carbonaceous shales is readily apparent. Practically no sand, other than a very thin lens here and there, is found in the *Discorbis* zone. The shales are very fossiliferous and many encrustations of shells make drilling decidedly slower than in the overlying formations.

Heterostegina zone.—The *Heterostegina* zone (marked by *Heterostegina* cf. *H. antillea*) underlies the *Discorbis* zone and is found at an average depth of 4,340 feet. The upper portion of this zone, approximately 25 feet, consists mostly of silty sands interspersed with sandy shales and a few thin lenses of shale. An exception is found on the western edge of the field, where the upper sand lenses of the *Hetero-*

stegina zone show a tendency toward a gradation into shales and in some areas are entirely absent.

The beds in the upper portion of the *Heterostegina* zone are irregular in character and close correlation from well to well is rendered difficult. Although the greater portion of the beds toward the top of this zone are sand, a large amount of the pore space between the sand grains is completely filled at irregular intervals with finely diffused shale particles, rendering those areas impervious to the passage of gas and liquids and causing the porous reservoir areas to occur as irregular pockets or lenses, which are largely charged with gas. A considerable amount of induration also occurs at irregular intervals.

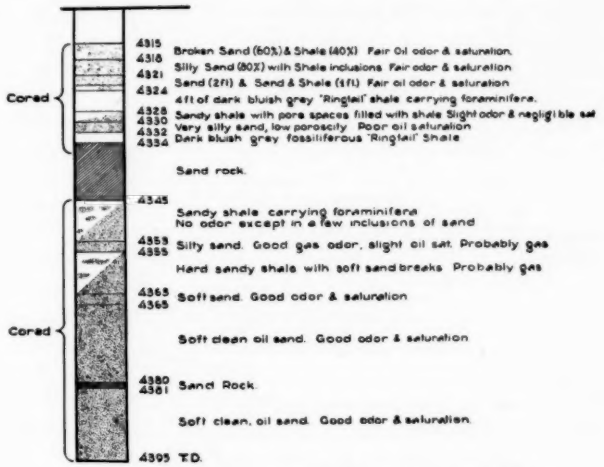
Cored
Cored
4315 Broken Sand (60%) & Shale (40%) Fair Oil odor & saturation.
4316
Silty Sand (80%) with Shale inclusions Fair odor & saturation
4321 Sand (2ft) & Sand & Shale (1ft) Fair oil odor & saturation
4324
4 ft of dark bluish grey "Ringtail" shale carrying foraminifera.
4328 Sandy shale with pore spaces filled with shale Slight odor & negligible sat
4330 Very silty sand, low porosity Poor oil saturation
4332
4334 Dark bluish grey fossiliferous "Ringtail" Shale
Sand rock.
4345
Sandy shale carrying foraminifera
No odor except in a few inclusions of sand
4353 Silty sand. Good gas odor, slight oil sat. Probably gas
4355
Hard sandy shale with soft sand breaks Probably gas
4363 Soft sand. Good odor & saturation
4365
Soft clean oil sand. Good odor & saturation
4380 Sand Rock.
4381
Soft clean, oil sand. Good odor & saturation.
4395 T.D.

FIG. 4.—Ideal sand section in Greta field. Texas Gulf Production Company's J. M. O'Brien No. A-2.

There is no line of demarkation between the upper and lower portions of the *Heterostegina* zone, but in the lower portion of the zone the sands are found to be markedly cleaner and the proportion of sand to shale is decidedly greater than in the overlying portion. The lower portion of this zone is found to carry a much greater saturation of oil than the upper. This section is shown in Figure 4.

The thickness of the *Heterostegina* zone and the position of the top of the Frio in the principal producing area are not known, for there has been no deep exploration within the area of the 4,400-foot "Greta" sand. Drilling just off the periphery of the 4,400-foot producing area,

however, shows a thickness in Atkins and O'Neal's Welder No. 1, on the north, of 292 feet and a thickness in Nesral Oil Company's Ira Heard No. 1, on the east, of approximately 152 feet.

Marginulina zone.—The *Marginulina* zone of the Middle Oligocene (marked by *Marginulina* cf. *M. philippinensis*) has not been found at Greta.

Frio formation.—The top of the Frio beds lies approximately at the base of the *Heterostegina* sand. In Atkins and O'Neal's Welder No. 1, just off the north edge of the field, the contact of the two formations was found at an approximate depth of 4,686 feet. East in the Nesral Oil Company's Ira Heard No. 1, the contact was found at an approximate depth of 4,650 feet.

The Frio formation at Greta consists principally of firmly packed, greenish gray, and in some horizons purple, shales. In general the distinction between sands and shales is not sharp. The sands ordinarily contain sufficient shale particles and volcanic ash to completely close the pore spaces; the shales contain sufficient arenaceous particles to warrant the term "sandy shale." This fact makes it extremely difficult for drillers to log the formations accurately without the use of the core barrel. In some portions of the Frio almost pure shales are encountered, while in other portions almost clean sands are found. The latter are in most cases thin lenses, either firmly packed or somewhat indurated. It is noticeable that although a few fairly thick Frio sands have been logged at Greta, the only production from that formation has been obtained from thin lenses of sand not exceeding 12 feet in thickness.

The Frio production at Greta is limited to a few wells on the eastern edge of the field and is obtained at an average depth of 5,900 feet. It is probable that this horizon is near the base of the Frio.

Vicksburg.—The beds below the Frio have not been explored at Greta, but there is a reasonable indication that it is underlain by the Vicksburg beds since the latter are known to exist in the O'Connor field at the north, in the Refugio field at the south, and at a point several miles directly up dip near the Refugio-Goliad county line.

STRUCTURE

The Greta field has the form of a rather irregular elongate oval, measuring approximately 20,000 feet along its major axis, N. 22.5° E., and 12,000 feet along its minor axis, S. 67.5° E. The real extent of the field is roughly 5,000 acres. With the exception of one small area on the east flank with six wells in the 5,900-foot Frio "pay" and a larger area on the southeastern portion with twenty wells producing from the

Catahoula, the field derives its production from the "Greta" or 4,400-foot *Heterostegina* sand.

The *Heterostegina* zone sand lies nearly flat across the main portion of the field. Contouring on top of this zone (Fig. 2), situated immediately over the top of the pay sand, shows a number of irregular ridges and depressions, but in general the beds lie horizontally with surprising uniformity and regularity. The greatest difference in subsea depths to the top of this zone is approximately 20 feet.

Near the northeast, southeast, and southwest edges of the structure the beds show a dip outward from the periphery at a rate of approximately 200 feet per mile. Such abnormal dip accounts for closure in these directions.

Sufficient data are not now available to determine definitely whether closure on the up-dip, or northwestern, side is due to a lateral gradation of formations from sands into shales, to faulting, or to both conditions. There is evidence in wells along the northwestern edge of the field of a considerable amount of gradation from sands into shales, particularly in the top of the *Heterostegina* sand. Breakage, as shown in cores from some of these wells, strongly suggests faulting also. Inasmuch as there is evidence of much faulting running along strike and parallel with the coast, extending from the Nuco Oil Company's Bluntzer No. 1, in Nueces County (Fig. 1), through the Wellington Oil Company's Rooke No. 1, southwest of Woodsboro in Refugio County, through the west edge of Refugio oil field, and through certain portions of the O'Connor field, the latter being described by Getzendaner,[4] it is the writers' belief that normal faulting with the downthrow on the northwest probably occurs along the northwestern edge of the Greta field.

Many ideas have been advanced regarding the type and cause of structure at Greta. Seevers[5] suggests[6] that the structure may be deltaic in origin. The raising of overlying beds during or subsequent to deposition by a deep-seated salt plug, and the forming of a horst with lateral closure due to faulting are also ideas which have been advanced. The writers do not believe that data from drilling in the areas surrounding the field are sufficient at the present time to furnish proof as to the type and origin of the structure, but regard the following evidence as strongly suggestive of a flat sand shoal spread evenly

[4] A. E. Getzendaner, "McFaddin-O'Connor, Greta, Fox, Refugio, White Point, and Saxet Fields, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 4 (April, 1934), p. 519.

[5] H. N. Seevers, geologist, Atlantic Oil Company, Corpus Christi, Texas.

[6] July meeting, 1934, San Antonio Geological Society.

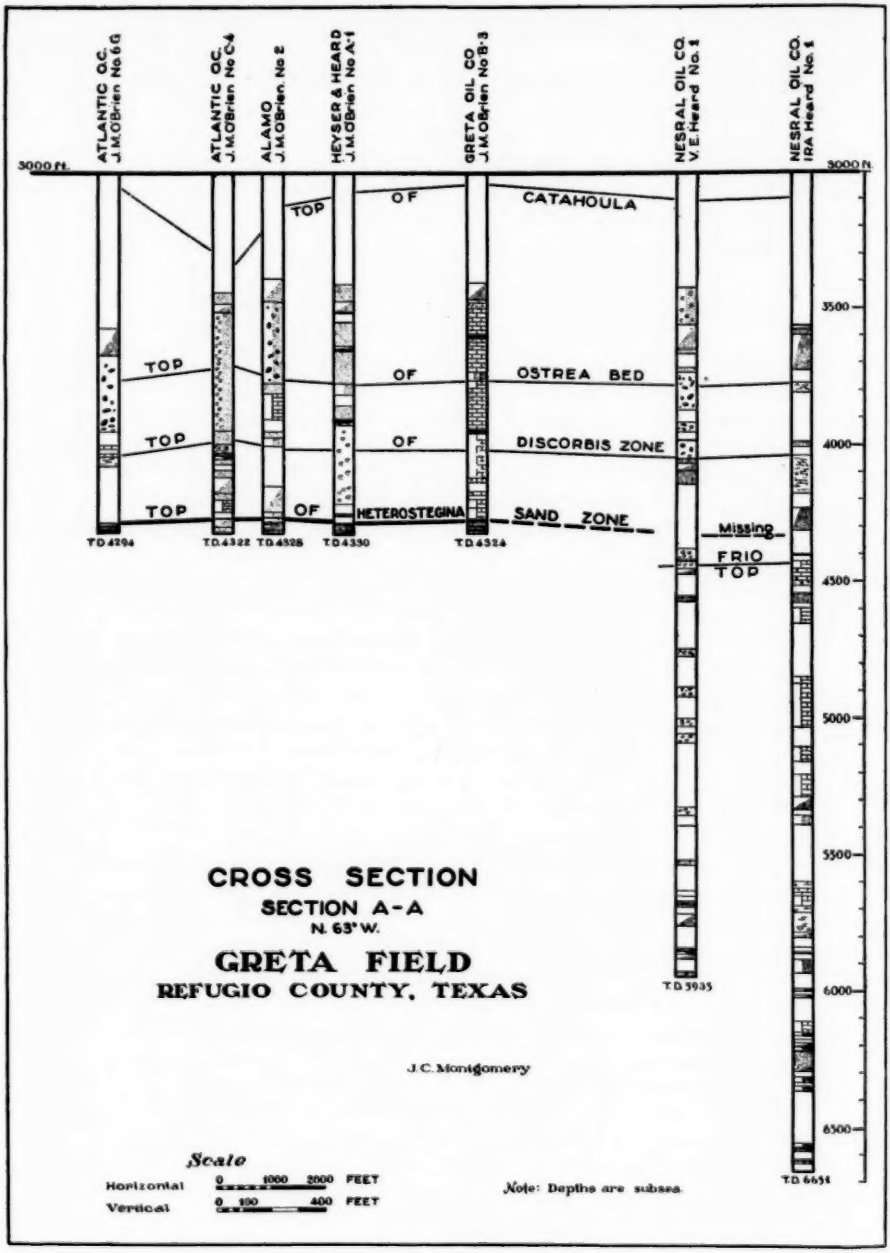

FIG. 5.—Cross section *AA* through Greta field.

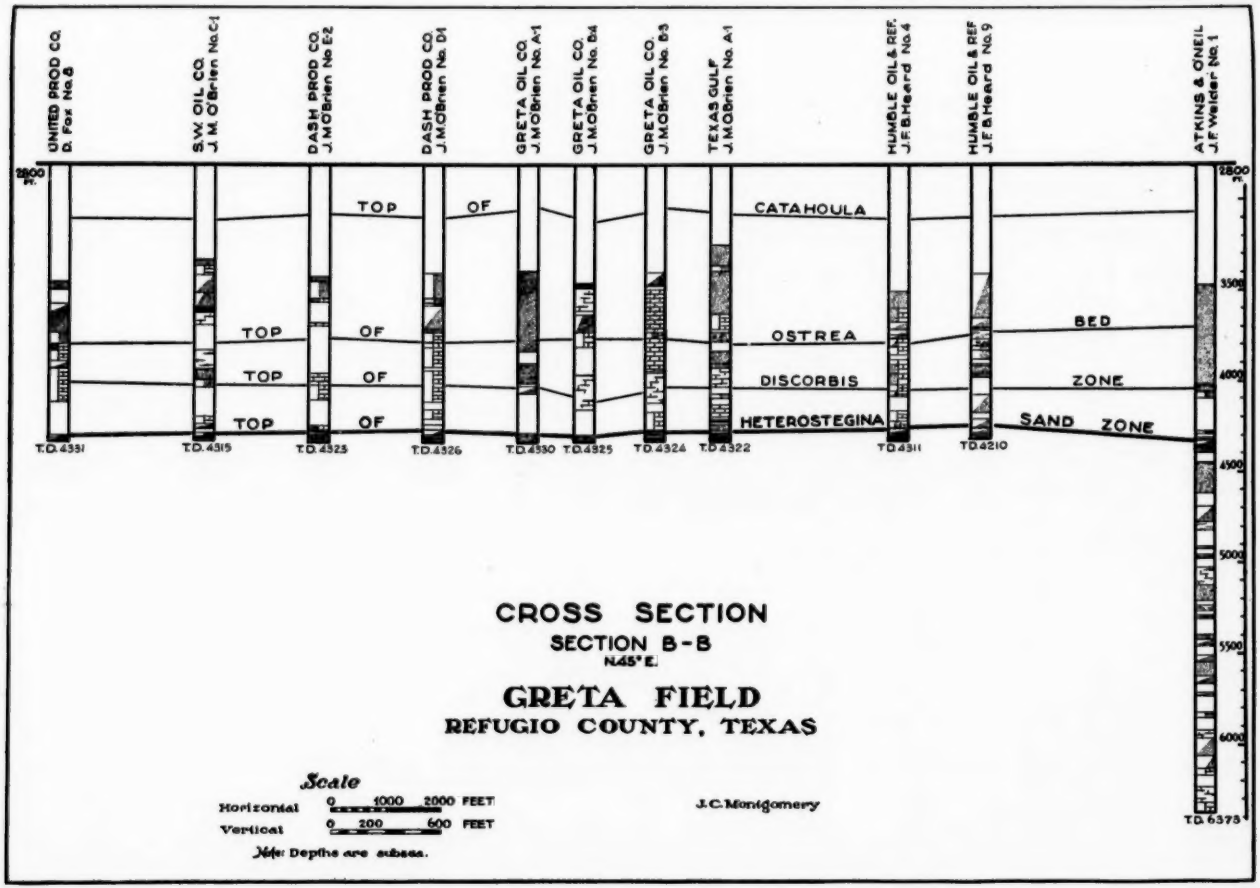

FIG. 6.—Cross section *BB* through Greta field.

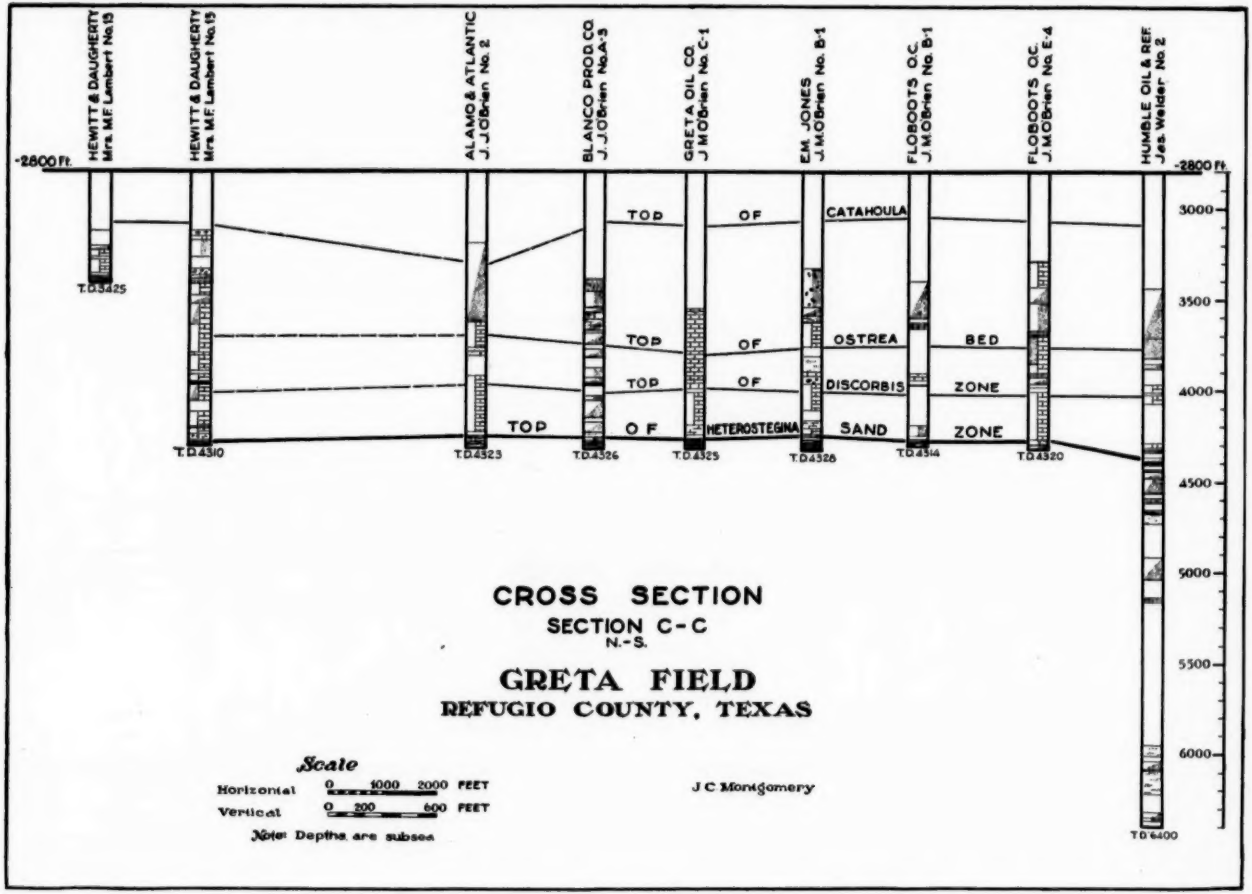

FIG. 7.—Cross section *CC* through Greta field.

over a terrace situated upon an anticlinal nose and closed by a fault on the up-dip, or northwest flank.

Contours on top of the *Heterostegina* zone showing a flatness of the producing beds, except for irregular ridges and depressions, with a variation in subsea depths not exceeding 20 feet, suggest a shore-line type of deposition, probably a shoal.

The dip of the beds off the edge of the structure at an approximate rate of 200 feet per mile northeast and southwest can not be considered normal regional dip, both because of the abnormal rate and because of the direction of the dips. The fact that partially saturated *Heterostegina* sands are found with apparent regularity down these slopes suggests that the beds are on the sides of an anticline and are connected with the beds overlying the top of the structure.

The slope of the beds off the southeast edge of the field follows the directional course of the normal regional dip, but their rate of dip is abnormal, a condition which would be expected immediately off the edge of a terrace.

The presence of a fault along the northwest edge of the structure, as suggested by the evidence of breakage in wells on this flank and by the known existence of faults along the same strike in the region, will be determined only by further exploration.

The 3,500-foot Catahoula and the 5,900-foot Frio producing horizons are extensions of the main field due to probable closing of their sands against the structure. Figures 5, 6, and 7, cross sections through the field, as indicated in Figure 2, graphically show these relationships.

Fig. 7.—Cross section *CC* through Greta field.

PRODUCTION

Greta is still a young field and not many decline data are available. The writers have not attempted a detailed study of reserves. Present[7] proration orders permit the production of 12,925 barrels per day for the Greta sand and 150 barrels per well per day from the 5,900-foot sand until such production from the 5,900-foot sand shall be 1,500 barrels per day for all wells in that sand.

Production and pressure data for the field up to January 1, 1935, follows.

[7] January 25, 1935, order.

Month	*Monthly Total Production in Barrels*	*Date*	*Average Reservoir Pressure at 4,300 Feet Subsea (Pounds per Square Inch)*
May, 1933	4,387		
June	18,457		
July	89,341		
August	182,301		
September	244,239		
October	220,941		
November	225,517		
December	231,441		
January, 1934	244,637		
February	231,025	Feb. 22, 1934	1,920
March	258,721		
April	234,204	April 26, 1934	1,880
May	300,813		
June	291,938		
July	296,926	July 9, 1934	1,867
August	437,868		
September	426,214	Sept. 15, 1934	1,816
October	391,626		
November	388,358	Nov. 23, 1934	1,805
December	406,100*		

* Estimated.

ANALYSES OF TYPICAL GRETA CRUDES

	Greta Crude 4,400-ft. sand	*Greta Crude 5,900-ft. sand*
Gravity, API	23.0°	36.7°
Saybolt Viscosity	62 at 100°F.	34 at 100°F.
Flash	195°F.	Room temp.
Sulphur	0.15%	0.11%
Color	Light green	466 Lovibond
Products		
	Gas oil 60%	400 E.P. Gasoline 36.7%
	Gravity 27.8°	Gravity 53.4°
	Flash 196°F.	Octane 56
	Sulphur 0.10%	Sulphur 0.04%
		Per cent at 212–16
	Lube distillate 30%	Per cent at 284–53
	Gravity 19.2%	
	Flash 375°F.	Kerosene distillate 18.2%
	Visc. 487 at 100°F.	Gravity 37.9°
	Cold test 0°F.	R.O. Visc. 475
	Sulphur 0.24%	Sulphur 0.06%
		Final boiling point 482°F.
	Bottoms 10%	
	Gravity 8.8°	
		Gas oil 25.1%
		Gravity 30.0°
		Flash 212°F.
		Pour 0°F.
		Sulphur 0.11%
		Cracking stock 13.4%
		Gravity 19.2°
		Sulphur 0.21%
		Analine point 154
		Bottoms 6.3%
		Gravity 10.0°

Production practice.—Wells are spaced regularly, one to about each 25 acres. Heavy-duty rotary rigs, customarily equipped with hydraulically operated blow-out preventers, enable wells to be completed in about 30 days. The usual casing program is to set 1,300 feet of 10- or 12½-inch surface casing followed by setting 7-inch pipe either above or about 25 feet below the top of the producing sand. Within ½ mile of a blow-out it is customary to set an additional string of approximately 300 feet of 13⅜ to 16-inch casing and cement it all the way to the surface to seal off gas-charged Lissie sands.

Early operations showed that setting in the gas zone in the top of the productive sand resulted in excessively high gas-oil ratios, and the later practice of landing the 7-inch casing about 25 feet in the sand horizon has to a great extent eliminated this waste of reservoir energy. Figure 4 shows an ideal casing setting. An average of 30 feet of sand below the casing seat is drilled and usually set with 5-inch OD .015 Ga. screen and the well is washed in with clear water.

A well is allowed to clean itself on a ½- to ⅝-inch choke, which is gradually reduced to an orifice size which will permit production to conform with the allowable. Flow battery includes a high-pressure gas separator, gun-barrel tank and two or more 1,000-barrel stock tanks.

The Atlantic Pipe Line Company and the Texas Pipe Line Company have lines to the field which handle the production.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 4 (APRIL, 1935), PP. 560-561

DISCUSSION

NORMAL GEOTHERMAL GRADIENT IN UNITED STATES

The recent valuable paper by C. E. Van Orstrand on "Normal Geothermal Gradient in United States," in this *Bulletin*, Vol. 19, No. 1 (January, 1935), pp. 78–115, suggests certain further lines of work. The isocon map for Ordovician waters prepared by Dott in 1930, this *Bulletin*, Vol. 14, No. 9 (September, 1930), p. 1215, suggests the problem of the cause and method of increase of concentration at depth; and besides the suggestions made by Case, it had occurred to me that it might be due to an imbibition or absorption of water in chemical reactions such as are caused when volcanic glass changes to bentonite.

Van Orstrand's paper also suggests that an effect upon the isotherms would be produced according as such diagenetic reactions absorbed heat and were endothermic or gave out heat and were exothermic. It would be interesting to study Van Orstrand's results and plot them upon Dott's map or a similar map brought up to date.

I would also take occasion to call attention to my discussion in Volume 110 of the *Transactions of the American Institute of Mining Engineers*, and say that the excess of soil temperature over air temperature in some of the Canadian mines (see Van Orstrand, pp. 111–14) is large, and I am quite sure is largely due to the blanketing effect of snow. Now this effect may change when the country is cleared of forests and burned over, and a permanent change of this sort will slowly be propagated some distance down. Van Orstrand (p. 91) makes one remark as to which he agrees with me that it applies rather to the pure instrumental error than to the geological and physical factors:

> the errors are assumed to vary inversely as the square root of the depth, that is, the errors of the observed temperatures are supposed to diminish with the depth. There is no justification for this assumption, . . .

This he agrees with me may apply to the instrumental observations, but he writes:

> Taking into account the three physical factors which you mention—climatic variation, phreatic circulation, and long continued ventilation in mines—the probable errors, insofar as these factors alone are concerned, should diminish with depth as you suggest. In other words, these factors, and possibly some others, should be included along with the instrumental errors in arriving at a correct weight or probable error.

I think, therefore, that the rate of heat increase in the bottom thousand feet is significant.

ALFRED C. LANE

BARNUM MUSEUM, TUFTS COLLEGE
MEDFORD, MASSACHUSETTS
February 5, 1935

"BIBLIOGRAPHY" OR "REFERENCES"?

Perhaps as a matter of minor importance, and yet one which always raises a question in the mind of at least this reader of the *Bulletin*, is the choice by authors of scientific papers of a heading for the list of collected reference works cited by them, or listed by them as bearing pertinently upon the subject matter of their papers.

Would it not be helpful if it were made a practice to use REFERENCES when the list is merely that of papers (and maps) cited in the preceding (and accompanying) article, while reserving the more inclusive and imposing heading BIBLIOGRAPHY solely for use for lists which represent the author's attempt to give a reasonably exhaustive list of those publications which have a bearing upon the topic or topics discussed?

If the heading BIBLIOGRAPHY is qualified by the subject, as for example, BIBLIOGRAPHY OF PETROLEUM, we would expect it to be a most exhaustive list, representing in itself a distinct contribution to the literature. If this usage were borne in mind, it would tend to lend more importance to those cases in which a *Bulletin* writer did choose to use the term BIBLIOGRAPHY in the precise sense here advocated.

Webster (New International Dictionary) says: "Bibliography (3) a list of *the* books relating to a *given subject* or author." (Italics used by present writer.)

W. ARMSTRONG PRICE

CORPUS CHRISTI, TEXAS
January 20, 1935

UPPER PERMIAN FORMATION OF DELAWARE BASIN OF TEXAS AND NEW MEXICO

CORRECTION

In the article, "Upper Permian Formation of Delaware Basin of Texas and New Mexico," by W. B. Lang, in the February *Bulletin*, on page 265, line 5, the word "brackish" should be *marine*.

PROBLEMS OF PETROLEUM GEOLOGY

CORRECTION

In line 14 of page 413 of the book *Problems of Petroleum Geology*, the name "Clear Fork" should be changed to read *Double Mountain*.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 4 (APRIL, 1935), PP. 562-581

REVIEWS AND NEW PUBLICATIONS

The Dinosaurs. A Short History of a Great Group of Extinct Reptiles. By W. E. SWINTON. 233 pp., 25 pls., 20 figs. London: Thomas Murby and Company (1934).

Once in a while a vertebrate paleontologist unbends and writes about some of his fossils in a way that makes them interesting even to the paleontological layman. When the writing is as good as Swinton's, and the fossil group as inherently interesting as the dinosaurs, the event merits the attention of *Bulletin* readers.

Swinton's first three chapters, dealing respectively with some elementary geological concepts, with a definition of the term "dinosaur," and with a sketch, illustrated by three maps, of Mesozoic paleogeography, serve very well as a brief introduction to dinosaurian lore.

Chapter IV is devoted to the problem of the origin of the dinosaurs. Along with certain other students, Swinton believes that they evolved, together with crocodiles and birds, from a primitive group of Triassic reptiles called the *Pseudosuchia*. These are poorly known small, slender reptiles, supposed from their long, thin legs to have been mainly leaping animals, but to have included some forms adapted to tree-climbing. Swinton follows Seeley and von Huene in believing that lizard-hipped and bird-hipped dinosaurs came from different members of the *Pseudosuchia*, the latter from more advanced members. He points out that the two orders of dinosaurs are distinguishable on several anatomical grounds, although in their more conspicuous features they have many resemblances. Both groups were originally bipedal, for example, but some of the later members of each order acquired a quadrupedal habit. Both groups were chiefly herbivorous, moreover, although many of the well known representatives of the lizard-hipped group acquired carnivorous habits.

With reference to their other characteristics, the author remarks that the dinosaurs were no doubt thoroughly reptilian, just as their skeletons suggest. They breathed with lungs, laid eggs, and had a smooth or scaly skin, without hair or feathers. Though in all probability cold-blooded, it is likely that the larger ones, at any rate, retained considerable body heat for fairly long periods after one of the outbursts of activity that may be presumed to have interrupted their usual reptilian torpidity. Their food requirements, as measured by mammalian standards, were probably small. It is suspected that many of the carnivorous forms may have fed, at least partly, upon the bodies of the dead. The giant sauropods, with hardly any brain and scarcely more impressive mouths and jaws, must have wallowed in an abundance of soft and luscious swamp vegetation, but of this we can only speculate.

Chapter V deals with Anatomy and Classification. The skeletal elements, especially skull and hip-bones, are clearly illustrated and described. With reference to brain-size, it is pointed out that *Triceratops* carried off the honors, with the smallest brain in proportion to the size of the skull of any land-living vertebrate. *Stegosaurus*, another armored dinosaur, was also noteworthy, with a two-and-a-half-ounce brain and a body weight greater than

that of an elephant. As a recompense, however, it had a "sacral brain" in the region of the hips which was twenty times as large as the one in its skull. Concerning most of the soft parts of the dinosaurs, not much is known. Casts of the skin of a few species have been found, and from the fact that the dinosaurs were genuine reptiles, hair and feathers are inferred to have been absent from all. Egg-laying has been demonstrated by occasional discoveries in different parts of the world, and stomach stones have been found in such relations with skeletons as to suggest that they were used for the attrition of food.

The classification of dinosaurs adopted by the author, though not "strictly scientific . . . is very convenient." It may be summarized as follows.

Super-Order *Dinosauria*

Order I. *Saurischia*, the lizard-hipped dinosaurs
- Sub-Order I. *Theropoda*, lizard-hipped bipeds of carnivorous habit. Examples are *Antrodemus* (*Allosaurus*) and *Tyrannosaurus*
- Sub-Order II. *Sauropoda*, plant-eating quadrupeds. *Brontosaurus* and *Diplodocus* are well-known examples

Order II. *Ornithischia*, the bird-hipped dinosaurs; all plant-eaters
- Sub-Order I. *Ornithopoda*, bipedal, beaked, and bird-footed forms. Well-known examples are *Iguanodon* and *Trachodon*
- Sub-Order II. Unnamed, but includes four-footed forms with armor. Examples are *Stegosaurus* and *Triceratops*

Chapters VI, VII, VIII, and IX are devoted to these four sub-orders. They constitute the heart of the book, of course, and abound in graphic descriptions of the highly varied dinosaurs known from different parts of the world. Though interesting throughout, these chapters leave little for a reviewer to do, except to suggest that they be read. Chapter X, which treats of "Dinosaurs and Disease," mentions some of the diseased and fractured bones that have occasionally come to light. It also discusses the dinosaurs that have been found preserved in "opisthotonic" posture, that is, with the head bent strongly backwards, and the legs stretched out in most uncomfortable attitudes. It is pleasanter to believe, with the author, that these attitudes were acquired by the animals after death.

Chapter XI deals with that perennial puzzle, the inspiration of so many fanciful hypotheses, the cause of dinosaur extinction. Swinton's point of view will be sufficiently evident from the penultimate paragraph of the chapter.

> There was, therefore, no one particular cause, but rather a complex series of circumstances based on a fundamental geological change, complicated by racial old age (phylogeronty), lack of plasticity, both physical and mental, of the dinosaurs themselves, and with, maybe, the added factors of food deficiency, climatic variation, and possibly epidemic disease.

Some additional suggestions on this subject will be made in later paragraphs of this review.

Chapter XII tells something about the occurrence of dinosaur bones and the technique of digging them up and preparing them for study; also about the mysteries of mounting them for exhibition, and the places where such exhibits may be seen. Chapter XIII, the last in the book, points out that in addition to its interest, the study of dinosaurs has occasionally thrown a gleam of light on other apparently unrelated fields of knowledge. Though most of these gleams appear to be more curious than useful, nobody who has

read the first 12 chapters will mind. He will realize too clearly that the interest of the subject justifies its devotees.

The volume is illustrated by 25 plates, mostly photographs of dinosaur reconstructions, and 20 text figures. It has also an alphabetical list of British dinosaurs, and a useful glossary of technical terms.

The reviewer believes that anyone who may be led to open this book will not only read it with pleasure but will always thereafter feel an increased interest in the literature dealing with the dinosaurs and their times. Having occasionally yielded to such an interest himself for a number of years, he takes pleasure on this occasion in furnishing the recruits who are about to be made, with a small annotated list of books and papers. These are selected from among those publications of the last 20 years that throw light on the dinosaurs and their environment, and particularly on the question of why the dinosaurs died out everywhere with apparent suddenness at or near the end of the Cretaceous.

Concerning the extinction of one of Swinton's four dinosaurian suborders, there is little room for doubt. The huge, carnivorous theropods died out because they had become specially adapted to prey upon their even larger herbivorous fellows. After the passing of the latter, the theropods must have been profoundly embarrassed. There were no other large animals in the world, except perhaps some flightless birds ancestral to such giants as the Eocene Diatryma. These were hard to catch. The mammals were also hard to catch, and most of them so small as hardly to be worth the effort. Plant-eating had been given up so many million years before that the art could not be reacquired without delay. And delay was fatal.

Though simple, logical, and competent, this explanation for the demise of one-fourth of the dinosaurs is stressed by very few authors, and is omitted from consideration by many. If it is kept clearly in mind, however, it may serve as a standard by which to judge the hypotheses of other types that are preferred by many. A few of these appear in the following summary notes.

1. W. D. Matthew, "Climate and Evolution," *Annals New York Acad. Sci.*, Vol. 24 (1915), pp. 171–318.

On pages 275–80 Matthew sketches in masterly fashion the adaptation of the dinosaurs to their Mesozoic environment.

> The dinosaurs appear to be primarily a dry-land adaptation . . . of the primitive reptiles. Their most obvious adaptive characters lie in the long limbs and swift-running gait and the general parallelism to the ratite birds. As such, the conditions of life would tend to greater activity and higher development and enable them, when they reinvaded the swamps during the epochs of great swamp-extension, to reach greater size and dominance. It is these readaptations that are chiefly known to us and are apt to give the idea that the dinosaurs were distinguished by gigantic size and massive proportions . . . . There must have been multitudes of small dinosaurs, mostly inhabiting the upland, a smaller number living among the swamps and marshes, but we know comparatively little about them. Some notion of their numbers and variety in the Triassic is gained from the innumerable footprints spread over the Triassic shore-deposits of the Connecticut River. . . . From these and other fragments of evidence, we may reconstruct a concept of the dinosaurs as a dry-land adaptation developed during the arid Permo-Triassic climatic phase. . . . During the base-leveling and submergence and moist tropical climate of the Jura, these dry-land adaptations reinvaded the swamps and coast-marshes, the least specialized types . . . specializing into the peculiar Sauropoda, while the higher types retained more of their terrestrial habitat. . . . The drier uplands [of upper Jurassic and basal Cretaceous] must have been tenanted by lighter, smaller dinosaurs. . . .

In the Lower Cretaceous occurred a swing towards emergence and arid conditions, not extreme, but sufficient to wipe out the sauropod dinosaurs in the northern world. . . .

The giants of the Upper Cretaceous, Matthew continues, seem not to have evolved from the amphibious types of the Jurassic, but from dryland types. All the data thus seem consistent with the hypothesis that the dinosaurs were primarily adapted to upland life, but that the forms which happen to have been most frequently preserved as fossils were nearly all secondary readaptations to forest and swamp life. In partial confirmation of this hypothesis, Matthew notes that fossils of young dinosaurs have rarely been found; he suggests in explanation that the young may have spent their time in the ancestral home of the race—that is, in the continental interiors where erosion was dominant and fossilization uncommon.

This passage from one of Matthew's most stimulating papers has been summarized at some length because it gives an exceptionally clear, if hypothetical, picture of the dinosaurs at home.

2. W. D. Matthew, "Outline and General Principles of the History of Life," *Univ. California Syllabus Series* (1930). Chapter 18, "Dinosaurs and the Age of Reptiles."

In this much later paper, prepared for his elementary classes, Matthew sketched all too briefly his final conclusions on the cause of dinosaurian extinction. He suggests that birds, mammals, and dinosaurs originated about the same time, during the Permian stage of expanded continents and climatic extremes. Birds evolved feathers and wings, a good circulatory system, a constant temperature. They were thus fitted for life in cool, and even arid regions. The mammals developed hair instead of feathers, adaptable forelegs instead of wings, and did equally well with the temperature-regulating mechanism. They were thus fitted for life in cool, humid regions, and as a matter of fact probably lived in the polar regions during the later Mesozoic.

The dinosaurian reptiles, on the other hand, gained the advantage in the warm, humid regions, and managed to dominate the lands during the long stages of the Middle and Upper Mesozoic when the continents were largely warm, humid, and low. The Senonian, with swampy lands and chalky seas, saw the peak of those conditions. And always, when some of the coastal and swamp-dwelling forms became too highly specialized and shiftless to survive the occasional periods of inclement weather, or increased competition with some more active creature for food or space, or the rise of some other unfavorable condition, its place was taken by one of the smaller, more energetic dinosaurs from the interior. As the end of the Mesozoic approached, average continental elevation was much increased; swamp areas and shallow epicontinental seas were greatly restricted in area; and climatic extremes affected a greater part of the continental interiors. New types of forests were crowding out the cycads, and birds and mammals were being favored at the expense of the more active dinosaurs of the interior. Presently, like their dinosaurian predecessors in these same regions, the birds and mammals began crowding down into the swamps and coastal lowlands to compete with, and presently to displace, the huge, amphibious descendants of earlier upland dinosaurs.

This may serve to explain why the reign of the dinosaurs began when it did, and ended when it did. In both cases the fundamental background of cause may be found in the cyclic alternations of climate during geologic time (p. 155).

On page 142 of this little book there is an exceptionally graphic sketch of the dinosaurian family tree, with typical genera perched among the branches in appropriate attitudes. It makes clear the genetic and time relations of *Ornithischia*, *Saurischia*, *Ceratopsia*, and some of the other polysyllabic subdivisions of the group.

3. W. D. Mathew. Many of this author's other writings deal with dinosaurs, and still others with the paleontologic and geologic questions involved in the problem of their extinction. See, for example, "Fossil Vertebrates and the Cretaceous-Tertiary Problem," *Amer. Jour. Sci.*, 5th Ser., Vol. II (1921), pp. 209–27.

4. I. P. Tolmachoff, "Extinction and Extermination," *Bull. Geol. Soc. America*, Vol. 39 (1928), pp. 1131–48.

A good statement of the argument for racial old age and similar philosophical concepts.

5. H. F. Osborn, "Titanotheres of Ancient Wyoming, Dakota, and Nebraska," *U. S. Geol. Survey Mon. 55* (1929).

Chapter II treats of the North American environment of the titanotheres, which lived in the area recently relinquished by the best-known dinosaurs. Chapter XI discusses the causes of the evolution and extinction of the titanotheres and other animals. Copious references to earlier discussions, with important passages quoted from many of them. An elaborate bibliography begins on p. 889.

6. A. Morley Davies, *Tertiary Faunas*. Thomas Murby and Company (1934).

Chapter III gives a thoughtful discussion of the paleogeography and the marine faunas of the world at the time of dinosaurian extinction.

7. G. Heilmann, *The Origin of Birds*. D. Appleton and Company (1926).

Besides the comprehensive anatomical discussions, this book has some striking word pictures of Mesozoic birds in their environment, and some interesting reproductions of dinosaurs in action.

8. O. Abel, *Lebensbilder aus der Tierwelt der Vorzeit*. Gustav Fisher, Jena (1922).

This most readable and most instructive of paleontologic books gives several glimpses of dinosaurs in appropriate relation to their environment. Chapter X deals with the reptilian ancestors of birds, mammals, and dinosaurs "in the desert regions of the South African Karroo during the Permian." Chapter VIII, discussing conditions "along the Solenhofen strand of Upper Jurassic Bavaria," describes one of the rare small dinosaurs of the type assumed by Matthew and others to have peopled the Mesozoic uplands in vast numbers. Chapter VII gives a vivid account of *Diplodocus*, *Stegosaurus*, and their contemporaries in western America and eastern Africa about the end of the Jurassic. Of the many excellent accounts of the Morrison formation and its fossils, none is more interesting than this. Chapters V and VI, finally, treat of central United States in Upper Cretaceous (Niobrara) and Belgium in Lower Cretaceous (Wealden) time. *Triceratops* and *Iguanadon*, among others, come to life in these well-illustrated pages.

9. A. C. Seward, *Plant Life Through the Ages*. Cambridge (1931).

This book gives one of the latest and best accounts of land floras during the time of dinosaurian prosperity and decay. On page 379, Seward suggests that the great marine transgressions during the middle of the Cretaceous

may have had much to do with killing off the cycads and other older floral types and preparing the earth for the rapid spread of the angiosperms. He points out also that the earliest forests of angiosperms seem to have been in polar regions. As noted above, Matthew assumes that the ancestral mammals had their stronghold in the same regions. The suggestion is obvious, and has been made by several students, that the rise of mammals and the dying out of dinosaurs may have been correlated in some way with the change from ancient to modern types of forest.

10. C. E. P. Brooks, *Climate Through the Ages*. New York (1926).

Figure 23, page 206, shows graphically the author's interpretation of the major climatic cycles of geologic time. Late Upper Cretaceous is shown as one of the milder interruptions to the balmy climate assumed as normal for most of the past. Figures 27 and 28, page 274, show respectively the Mesozoic deserts and the Cretaceous ocean currents.

11. A. S. Romer, *Man and the Vertebrates*. Chicago (1933).

This readable volume has a good brief section on dinosaurs, but in the present connection is perhaps chiefly interesting for the author's speculations about the birds of the early Tertiary. From the fact that horses the size of a fox terrier were the contemporaries in ancient Wyoming of a bird seven feet tall, Romer suggests that the birds were for a time formidable rivals of the early mammals. In the later Tertiary, giant running birds have been found chiefly in regions isolated from the homes of the larger carnivorous mammals. Perhaps there was a time when the conditions were reversed. If so, and if we feel the need to call upon some unknown enemies to help make the latest Cretaceous an unfavorable time for the last of the dinosaurs, perhaps the Cretaceous ancestors of the Eocene *Diatryma* may prove useful. Like the vast majority of extinct birds, they are, of course, completely unknown to us. Unlike many of the other factors that have been called upon to combat the dinosaurs, however, there can be little doubt that such birds existed. Perhaps they offered keen competition to the dinosaurs, particularly to those small upland dinosaurs which during the whole Mesozoic served as the reservoir from which, on occasion, new inhabitants for the coastal swamps could be drawn to replace unwieldy forms that fell by the wayside.

Students who incline toward the philosophy of racial old age as the cause of dinosaurian extinction will not need all the references already given. Those who prefer to extinguish their dinosaurs by more tangible factors will of course, need many others. Particularly they will need such books as Krenkel's *Africa*, Obruchev's *Siberia*, and Grabau's *Stratigraphy of China;* books which permit one to form some notion of the succession of geographies throughout the world during the time when the dinosaurian drama was running its course.

RALPH D. REED

SOUTH PASADENA, CALIFORNIA
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"Paleozoic Plankton of North America." By RUDOLF RUEDEMANN. *Geol. Soc. America Mem. 2* (1934). 141 pp., 26 pls.

In spite of a title that may sound forbidding, this second memoir of the Geological Society's new series contains many passages of interest to geologists in general, and not a few to oil geologists in particular. This interest is due in part to the fact that much of the Paleozoic plankton is preserved in

black carbonaceous shales of the kind oil geologists often study; in part, also, to the fact that the author does not limit himself to a mere description of the organisms in question, but ranges widely over subjects as far apart as the peculiarities of modern sargasso seas and the theory of continental drift.

The memoir is divided into three parts. Part I deals with the more general problems, Part II contains the descriptions of fossils, and Part III consists of bibliography, plates, and index. Part III appears to be praiseworthy in all respects, and Part II is beyond the competence of the present reviewer. Part I, consisting of 64 large pages, deals with many controversial questions, of which a few will be mentioned in the paragraphs that follow.

Ruedemann states that the graptolites, with the exception of primitive benthonic *Dendroidea*, are generally agreed to have floated in the Paleozoic seas either by means of floats of their own, or by attaching themselves to seaweed. They

> are restricted to marine waters close to the continental margin. Their normal occurrence is linked with the great geosynclines of the east and of the west—the Appalachian and the Cordilleran . . . Marr[1] has shown that the European graptolite shales were deposited in embayments that opened to the Atlantic on the west and extended eastward into the continent, allowing currents and storms to carry the plankton of the open ocean far within the continental limits, just as today the tropical seaweeds (*Sargassum*) are still occasionally brought to the coast of Britain.

This passage deserves careful attention. The author returns to it on two or three later pages, always as if it were a datum. Marr proved that the Atlantic lay west of Europe during the Silurian, he says, and his own researches have shown that it also lay east of the Appalachian district. With the Atlantic thus doubly proved to have existed as early as the Silurian period, Wegener's hypothesis is completely shattered. It is therefore interesting to read Marr's paper, and see just what he proved and how he did it. An examination of his map (reproduced in the memoir under review as Figure 1) shows that the graptolite shales of Europe occur in bay-like areas closed on the east and open at least as far west as the present Atlantic coast. Neither the map nor Marr's text shows anything about the possibility that the bays extended still farther west, since Marr was not discussing continental drift. But of course, if America and Europe were at that time contiguous, as Wegener supposed, these bays must have extended westward across America. Marr not only does not disprove this possibility—he does not even mention it.

It may well be, of course, that to an expert on Paleozoic plankton the possibility is not a real one. Ruedemann apparently thinks so, and the reviewer has no desire to maintain the opposite. He wishes merely to question if either Marr or Ruedemann has proved anything about the Atlantic Ocean, although the latter writes repeatedly as if they had done so. Ruedemann implies that his evidence is decisive ("the most damaging evidence to the drift theory yet brought forward") and stresses the long period its acquisition has consumed ("a gradual process of elimination of working hypotheses . . . the result of a life-long study . . .") but nowhere spreads it before us. There are even passages here and there which raise the question, no doubt unjustifiably,

[1] J. E. Marr, "The Stockdale shales of the Lake District," *Geol. Soc. Quart. Jour.*, Vol. 81, Pt. 2 (1925), pp. 113-33.

whether or not the author has ever seriously tried to fit his facts into the paleogeographic frame assumed by the drift hypothesis.

We are told, for example, that the graptolites are planktonic and must therefore have floated into the Paleozoic geosynclines from an open ocean. We are not even told why they might not have evolved as special adaptations to life in the Paleozoic geosynclines themselves. Even if everybody can reasonably be expected to answer that question without help, why is the Atlantic Ocean specified? Why could not the graptolites have floated in from the Pacific or Arctic oceans? Grabau, who is quoted on page 63 as believing that they evolved entirely in the Indo-Pacific, must suppose that they did float in from the Pacific. Ruedemann is so convinced of the opposite, however, that he nowhere discusses the matter. The reader is thus left with no opportunity to see for himself how the supposedly important evidence from the Paleozoic plankton affects the question of continental drift.

The paleogeographic evidence, as acknowledged by Wegener himself, is of decisive importance in discussions of the drift problem. Wegener's own use of such evidence, in the opinion of his opponents at least, was sometimes question-begging, forced, and tainted by special pleading. It is thus the more to be regretted that most of the opposing paleogeographers have made so little attempt to apply the evidence to the problem in a broader, more judicious way. Too frequently the reader of such discussions is left with the feeling that the evidence is not really "damaging" to the drift theory—that in fact it has little or no relation to it—but that the paleogeographer has merely become accustomed to think of early geologic periods in terms of fixed continents and oceans, and refuses to think otherwise. Perhaps some day there will be among geologists a more general realization of the fact that the drift theory, wild as it may seem to a generation educated in an atmosphere of permanency, can only be refuted if it is taken seriously. It is far too ingenious and plausible to be annihilated between chapters in a slim volume dealing with something else.

Ruedemann argues that the fossil associates of the graptolites have in common some characteristics that "point, first, to a life environment for the graptolites provided only by the algal floras of the ocean." This conclusion necessitates a comparison with the faunas of modern littoral seaweeds and modern sargasso seas. He concludes that the modern littoral seaweed fauna is too rich and too locally varied to compare favorably with the fauna associated with the graptolites. Modern sargasso sea faunas, on the other hand, have, along with striking differences, enough resemblances to the graptolite faunas to suggest that the latter may have developed in Paleozoic sargasso seas. In the discussion of modern "gulf-weeds" (*Sargassum*) it is stated that they have thus far been found only free floating, but from the fact that many have stems it is assumed that they began as plants attached to the bottom.

> The weed is a tropical plant, and it is believed that it is torn from the Bahamas by the force of the waves and then caught in the eddy of the great system of Atlantic currents.

In his discussion of "Paleozoic plankton in general" the author makes numerous interesting suggestions. He quotes from Pia, for example, an account of recent observations made by E. Bacharach and M. Lefèvre and said to show

that many diatoms readily lose their siliceous cases on cultivation in gelatine and continue to live for months in this condition, a fact which indicates a relatively late acquisition of the frustule, and which, as Pia points out, reconciles the conflicting views of the geologists and the botanists.

He includes some remarks about the remarkable persistence of *Foraminifera*, many of which he considers to be practically "immortal" forms. These remarks appear to be based largely on the views of those older writers who lived before the modern study of *Foraminifera* began.

There is an interesting account of fossil "jelly-fish," some of which are diagnosed as *algae*. The absence of calcareous bryozoans from the pure graptolite beds is accounted for on Ruedemann's theory that bryozoans were represented during the Paleozoic "by the older branch of the class, the graptolites." The conodonts are discussed briefly, and reference is made to Gunnell's theory that the conodonts are the teeth, and the oil a derivative of the fat, of certain primitive fish (cyclostomes) that are supposed to have had habits like those of a modern salmon. If one of the other theories of the origin of conodonts turns out to be right, we shall be compelled to give up this theory of the origin of oil, or perhaps to modify it.

On conditions of black shale accumulation, Ruedemann seems to be able to agree fairly well with nearly everybody except Grabau. He holds, in other words, that the black shales accumulated in geosynclinal seas that were moderately deep, though not abyssal; that these seas were open to the ocean, with currents sweeping through them, but that

the bottoms where the black shale was deposited suffered from vegetable fouling and, therefore, unlike the mixed graptolite shale, had no bottom fauna.

In this connection the author reports some interesting observations made near the coasts of Denmark by Petersen and Jensen. In the inner fjords they found a black, foul-smelling bottom mud, which they attributed to imperfect circulation and oxygenation of the water. These bottoms are apparently barren of organisms. Ruedemann holds, however, that the graptolite shales were not formed in small fjords and embayments, but

in poorly aerated, deeper off-shore water in geosynclines, where only planktonic forms that drop to the bottom are found. The lack of aeration of the water results from the relatively weak vertical circulation in the troughs failing to reach deeper levels.

The Denmark black muds, mentioned in the preceding paragraph, appear to be similar to Norwegian muds suggested by Abel as possible counterparts of the Lower Jurassic bituminous shale of Holzmaden. The conditions of origin of the latter, and the circumstances that led to the preservation in it of many excellently preserved fossils, are discussed in Chapter IX of Abel's "Lebensbilder aus der Tierwelt der Vorzeit." Like the similar discussion in Ruedemann's book, this chapter of Abel's should be listed by oil geologists among the passages of paleontologic literature that bear directly on some of the fundamental problems of oil geology.

RALPH D. REED

LOS ANGELES, CALIFORNIA
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Guidebook of the Eleventh Annual Field Trip of the Shreveport Geological Society in Southeast Mississippi. Compiled by ROY T. HAZZARD and B. W. BLANPIED. 50 pp., maps, charts, 6 pls.

The excellence of the *Guidebook* provided for this field trip is to be highly commended. The *Guidebook* consists of 49 pages of text; a page of bibliography for the area under consideration; a map showing the localities visited; a diagrammatic cross section giving the compilers' opinions of the stratigraphic relationships; check lists by H. V. Howe giving ostracod and foraminiferal lists of the (new) Chickasawhay members of the Catahoula group in comparison with *known* faunules of the Byram (uppermost Vicksburg) and the Chipola (Lower, but not lowermost Miocene); a similar bryozoan chart by James McGuirt; a correlation chart by M. A. Hanna and Donald Gravell expressing their opinions regarding correlations of the Eocene Jackson, the Oligocene, and the Miocene Catahoula group of Mississippi, Louisiana, and Texas; and 6 plates of fossils. The *Guidebook* was compiled by Roy T. Hazzard and B. W. Blanpied.

Although not specifically discussed in the *Guidebook*, the compilers have kindly given the present reviewer the following information relative to the chronological development of ideas concerning the Miocene-Oligocene relationships in Wayne County, Mississippi, as outlined in the *Guidebook*, as follows.

In his discussion of the Oligocene Byram Calcareous Marl of Wayne County, Mississippi, C. Wythe Cooke in *U. S. Geol. Survey Prof. Paper 133*, page 13, considers his locality No. 6649 on the Chickasawhay River southeast of Waynesboro as Byram. This locality is listed in the *Guidebook* as Locality No. CW, Miocene-Upper Chickasawhay. In *U. S. Geol. Survey Prof. Paper 129*, page 80, Cooke calls attention to the change in lithologic character of the Byram at Waynesboro, the abruptness of the change suggesting the probability of an interruption in sedimentation. On the same page Cooke notes the 70-foot thickness of the Byram on the Chickasawhay River (Wayne County), which thickness of the Byram is inclusive of the Bucatunna and Chickasawhay members of the Miocene-Catahoula group as defined in the *Guidebook*.

J. T. McGlothlin, geologist for the Gulf Refining Company of Louisiana during 1930, mapped his "Bucatunna" sand and clay members of the Byram across Wayne County, Mississippi, failing to recognize, however, the volcanic character, the significant overlapping relationships, and variations in thickness of this member. McGlothlin's term of "Bucatunna" used in defining a lithologic unit in the beds of supposedly Byram age has been redefined in the *Guidebook* to designate the basal Miocene beds of Wayne County, Mississippi (and beds of equivalent age elsewhere through south Mississippi).

Early in 1934 field work in Wayne County, Mississippi, by Roy T. Hazzard and B. W. Blanpied, and independently by Sheridan A. Thompson, indicated the existence of two distinct lithologic units stratigraphically higher than McGlothlin's Bucatunna member. The names of Lower and Upper Chickasawhay were applied to these lithologic units by Hazzard and Blanpied. At the same time the variable thickness of the Bucatunna was noted. Prior to the detailed study of the fauna of the Lower and Upper Chickasawhay by Howe and McGuirt, the Miocene-Oligocene contact had been placed tentatively at the Lower-Upper Chickasawhay contact by Blanpied, Thompson, and Hazzard for the reason that the Lower Chickasawhay carried microfossils referred to *Arca lesueuri* and *Pecten poulsoni* by the United States Geological Survey, in addition to *Ostrea* cf. *vicksburgensis* and *Echinolampas aldrichii* (the latter determination being made by C. L. Moody), which assemblage of fossils was not found in the Upper Chickasawhay.

Early in 1934 Urban Hughes, of Laurel, Mississippi, discussed with several Shreveport geologists the evidence for placing an unconformity within the Byram in Smith County, Mississippi, based upon geological field work and shallow core drilling carried on in 1933 (and probably earlier). This distinct unconformity, first recognized by Hughes,

occurs at the base of his principal volcanic ash zone, which zone is equivalent to McGlothlin's Bucatunna member of the Byram. The overlapping relationships of the Bucatunna first recognized by Hughes in Smith County were subsequently found to exist in the Wayne County area.

The preliminary detailed study of the macro and microfaunas of the Lower and Upper Chickasawhay member by H. V. Howe and James McGuirt, with the assignment of these members to the Miocene, in conjunction with the field evidence that the Lower Chickasawhay rests comfortably on the Bucatunna and that the Bucatunna, in turn, rests unconformably on the Byram, are the reasons that the compilers of the *Guidebook* placed the Miocene-Oligocene contact in Wayne County at the base of the Bucatunna. The compilers did not agree with the correlation of the Upper and Lower Chickasawhay as presented by Hanna and Gravell in the Shreveport *Guidebook*, particularly since Hanna and Gravell attach little significance to the importance of the widespread erosional break at the base of the Bucatunna.

The introduction credits B. W. Blanpied, W. C. Spooner, Albert E. Oldham, Luther B. Smith, Jr., and W. O. George with the plane-table surveys and altimeter work, results of which were incorporated in the *Guidebook*.

STRATIGRAPHY

Under this heading there is given a generalized résumé of the geological features of the formations found in Clarke and Wayne counties, Mississippi, beginning with the Wautubbee marl of the Claiborne group and ending with the Pliocene Citronelle formation.

Diagnostic fossils for the marine members are given. Excellent descriptions are given of the Bucatunna and Chickasawhay members, new units of the Catahoula.

The Bucatunna is described as "a sequence of bentonitic clays, bentonite, and cross-bedded sand." The successive transgression of the Bucatunna across the Vicksburg from Marianna to Byram is demonstrated for the region.

The Chickasawhay members are: the Lower, a fossiliferous marly and chalky unit; and the Upper, a fossiliferous calcareous and marly clay unit.

On page 9 of the *Guidebook* it is stated, "The term 'Red Bluff Member' as used in this report is slightly different from Cooke's usage." Reference to C. Wythe Cooke's correlation chart, shown on page 9 of *U. S. Geol. Survey Prof. Paper 133*, apparently indicates that Cooke considered the "Forest Hill sand" to be the time equivalent of the "Red Bluff clay." The *Guidebook* redefines the Red Bluff member as "the approximate 20 feet of marine beds which conformably underlie the Forest Hill Member, an essentially nonmarine member; and overlie, apparently conformably, the Yazoo clays." Unfortunately Hilgard's type locality of the Red Bluff group, which is exposed in the bluffs of the Chickasawhay River near Shubuta, was not visited.

In the portion of the section called Yazoo at Shubuta, the faunule associated with *Marginuline cocoaensis* Cushman occurs. This faunule has been considered Yazoo by micropaleontologists. However, such supposedly Vicksburgian species as *Bolivina caelata* Cushman and *Clavuline byramensis* occur with this faunule in wells and on the surface in southeast Mississippi and southwest Alabama. Thus it seems to the reviewer that the *Marginulina cocoaensis* zone, from the foraminiferal evidence at least, belongs with the Vicksburg group.

The Vicksburg-Jackson confusion is no doubt due in large part to the

fact that the type Vicksburg and the type Jackson left intervening gaps, the Forest Hill, Red Bluff, and Yazoo, the latter two which may in part overlap.

PRELIMINARY PALEONTOLOGIC ANALYSIS OF THE UPPER AND LOWER CHICKASAWHAY MEMBERS OF THE CATAHOULA FORMATION—HENRY V. HOWE

Dr. Howe brings out the lack of known microfauna of the Tampa and Chattahoochee, making these lowermost Miocene beds (of U. S. Geol. Survey usage) unavailable for comparison. He therefore has used the Chipola (next lowest Miocene) for comparison along with the Byram, the uppermost Oligocene (of U. S. Geol. Survey usage).

On the basis of ostracods Howe concludes that the Chickasawhay is neither Chipola nor Byram, although a few species range either way. Several of the ostracods show identity with species from beds considered Miocene in Haiti. In contrast with the *Ostracoda*, the *Foraminifera* in considerable number range down into the Byram and up to the Chipola. The fact that 40 per cent of the Upper Chickasawhay and 42 per cent of the Lower Chickasawhay foraminifers are also found in the Byram is startling in view of the definite field evidence of the erosional unconformity at the base of the Bucatunna. Fifty per cent of the Upper Chickasawhay and 49 per cent of the Lower Chickasawhay *Foraminifera* range into the Chipola or higher.

Howe concludes the Chickasawhay members fall within the Tampa-Chattahoochee of Florida, which the writer feels he has amply demonstrated.

Howe also discussed the larger fossils, calling attention to past errors.

BRYOZOA OF THE UPPER AND LOWER CHICKASAWHAY MEMBERS OF THE CATAHOULA FORMATION OF WAYNE COUNTY, MISSISSIPPI—JAMES MCGUIRT

Bryozoan evidence corroborates that of the *Foraminifera* and *Ostracoda*, four species being known from the Miocene, five species from beds the Oligocene age of which is considered questionable.

C. I. Alexander is then quoted using generic occurrence and abundance to strengthen the Miocene assignation of the Chickasawhay members. While this is orthodox procedure, the writer does not believe it sound, generic ranges being continuously extended, and in this case the added weight of evidence is certainly not needed.

M. A. Hanna and Donald Gravell are quoted as stating that the *Lepidocyclina* occurring in the Lower Chickasawhay appear to be identical with the *Lepidocyclina* of the Antigua formation of Antigua Island. The compilers continue,

> Vaughan places the Antigua formation in the Middle Oligocene (see p. 9, *U. S. Geol. Survey Prof. Paper 133*, where Cooke correlates the Antigua with the Glendon (Middle Vicksburg) following Vaughan) . . . the base of the Lower Chickasawhay member is separated from the Glendon limestone by forty feet of sediments; and an erosional hiatus of some magnitude. . . .

If both the Glendon and Lower Chickasawhay are closely akin to the Antigua, the question logically arises "Should not the faunas of the Glendon and Lower Chickasawhay be closely akin?" The compilers conclude that two distinct horizons must be recognized.

HANNA & GRAVELL

	GROUPS	TEXAS SECTION (SUB-SURFACE)	LOUISIANA SECTION (SUB-SURFACE & SURFACE)	MISSISSIPPI SECTION (SUB-SURFACE & SURFACE)
MIOCENE	CATAHOULA GROUP	UPPER ASH ZONE CATAHOULA (RESTRICTED)	CATAHOULA	CATAHOULA
		(MARINE DOWNDIP)	(MARINE DOWNDIP)	UPPER CHICKASAWHAY BEDS
OLIGOCENE		DISCORBIS ZONE (RESTRICTED) HETEROSTEGINA - MIOGYPSINA ZONE MARGINULINA ZONE	DISCORBIS ZONE (RESTRICTED) HETEROSTEGINA - MIOGYPSINA ZONE MARGINULINA ZONE	HETEROSTEGINA - MIOGYPSINA ZONE (PRESENT DOWN DIP)
	?			
	LIMESTONE CREEK GROUP	LOWER ASH ZONE (FRIO)	LOWER ASH ZONE (FRIO)	LOWER CHICKASAWHAY
				BUCATUNNA BEDS
	VICKSBURG GROUP			BYRAM MARL
				GLENDON LIMESTONE
				MARIANNA MARL
TRANSITION OLIGOCENE JACKSON		? ? ?	? ? ?	
	RED BLUFF GROUP (HILGARD 1860)	RICE SAND ZONE (CORRIGAN)	RICE SAND ZONE (CORRIGAN)	FOREST HILL SAND
		BLACK SHALE AMMOBACULITES TEXTULARIA WARRENI ZONE HAPLOPHRAGMOIDES	RED BLUFF SANDS (PRESENT DOWN DIP)	RED BLUFF CLAY
JACKSON	DANVILLE LANDING GROUP	UVIGERINA JACKSONENSIS ZONE MASSILINA PRATTI ZONE	DANVILLE LANDING BEDS	DANVILLE LANDING BEDS COCOA SAND OF CUSHMAN
	YAZOO GROUP	TEXTULARIA HOCKLEYENSIS ZONE (YAZOO)	TEXTULARIA HOCKLEYENSIS ZONE (YAZOO)	?
		TEXTULARIA DIBOLLENSIS ZONE (YAZOO)	TEXTULARIA DIBOLLENSIS ZONE (YAZOO)	COCOA POST OFFICE SAND BEDS LOWER YAZOO
	MOODY'S BRANCH GROUP	CAMERINA ZONE (MOODY'S BRANCH)	CAMERINA ZONE (MOODY'S BRANCH)	MOODY'S BRANCH
(1)	YEGUA GROUP	NONIONELLA COCKFIELDENSIS ZONE (UPPER YEGUA)	YEGUA (COCKFIELD)	YEGUA

(1) TRANSITION JACKSON & CLAIBORNE

ISRAELSKY

	GROUPS	TEXAS SECTION (SUB-SURFACE)	LOUISIANA SECTION (SUB-SURFACE & SURFACE)	S E MISSISSIPPI SECTION (SUB-SURFACE & SURFACE)
MIOCENE	CATAHOULA GROUP	UPPER CATAHOULA	UPPER CATAHOULA	CATAHOULA
		DISCORBIS ZONE (RESTRICTED)	DISCORBIS ZONE (RESTRICTED)	
		HETEROSTEGINA - MIOGYPSINA ZONE	HETEROSTEGINA - MIOGYPSINA ZONE	MET IN WELLS NONMARINE CHICKASAWHAY
		MARGINULINA ZONE	MARGINULINA ZONE	
		LOWER CATAHOULA	LOWER CATAHOULA	BUCATUNNA
		RICE SANDS	RICE SANDS	
OLIGOCENE	VICKSBURG GROUP	AT LEAST IN PART PRESENT FRIO (OF BAILEY) (2) BELIEVED TO BE OUTCROP EQUIVALENT	IN BEAUREGUARD PARISH VICKSBURGIAN FORAMINIFERA OCCUR ABOVE AND BELOW TEXTULARIA WARRENI	BYRAM MARL
				GLENDON LIMESTONE
				MARIANNA MARL
				FOREST HILL SAND
				RED BLUFF CLAY
?		TOP-RANGE-OF-MARGINULINA-COCOAENSIS		
	UPPER DANVILLE LGD BEDS	UVIGERINA JACKSONENSIS AND MASSILINA PRATTI ZONES	UPPER DANVILLE LGD BEDS	COCOA "SD" OF CUSHMAN
				ABSENT
JACKSON	YAZOO GROUP	TEXTULARIA HOCKLEYENSIS ZONE	TEXTULARIA HOCKLEYENSIS ZONE	
		TEXTULARIA DIBOLLENSIS ZONE	TEXTULARIA DIBOLLENSIS ZONE	COCOA POST OFFICE SD BEDS OF CODNE
				LOWER YAZOO
	MOODY'S BRANCH GROUP	CAMERINA ZONE	CAMERINA ZONE	MOODY'S BRANCH
(1)	YEGUA	NONIONELLA COCKFIELDENSIS AND EPONIDES YEGUAENSIS ZONES	COCKFIELD	YEGUA

(1) TRANSITION JACKSON AND CLAIBORNE

(2) BAILEY, T. L., UNIV. TEXAS BULLETIN 2645, 1926

Short notes on the "Catahoula" above the Chickasawahay and the Citronelle follow.

DESCRIPTION OF LOCALITIES

Excellent descriptions of the localities visited with fossil lists of selected samples by M. A. Hanna, Donald Gravell, C. I. Alexander, and H. V. Howe compose the remainder of the book.

Description of the Shubuta locality samples brings out the fact that the "Cocoa sand" (*Marginulina cocoaensis*) faunule of Cushman is described from marls above the Cocoa sand as finally described by Cooke. This is substantiated by other collections much nearer the type Cocoa sand locality examined by Hanna, Howe, the reviewer, and others. The faunule list of the Cocoa sand at Shubuta shows it to belong in the Lower Jackson (*Textularia dibollensis* zone), with the intervening beds missing, as is brought out by Hanna and Gravell on their correlation chart on the preceding page.

The chart by Hanna and Gravell is here reproduced, substituting Upper and Lower Chickasawhay as used in the main text, for Chickasawhay and Limestone Creek beds as used by Hanna and Gravell. For contrast the reviewer shows his conception of correlation. Both views are based on more or less the same evidence, and the disagreement probably shows nothing more than a lack of detailed knowledge.

MERLE C. ISRAELSKY

HOUSTON, TEXAS
February, 1935

Oil and Gas Geology of the Gulf Coastal Plain in Arkansas. By W. C. SPOONER. Parke-Harper Printing Company, Little Rock, Arkansas (1935). Referred to as *Arkansas Geological Survey Bulletin No. 2.* 548 pp., 26 pls., 95 figs., 57 tables. Cloth, $3.80, postpaid.

The Arkansas Geological Survey has succeeded in presenting to the petroleum industry a very creditable summary of the Cretaceous oil and gas development in the state under the above title.

The author, an eminent student of Coastal Plain geology, was regularly engaged as assistant State geologist of Arkansas during the years 1927 and 1928 and gave his full time to a study of the wealth of geologic data which had become available from the thousands of wells drilled in search of oil and gas in the Cretaceous formations of the state. His serious illness prevented the final completion of the report early enough to permit its publication while State funds were still available. George C. Branner, zealous State geologist, was undismayed by lack of appropriations in the succeeding lean years and labored unceasingly and searched untiringly for ways and means of making the information available to the public. This reviewer has personal knowledge of the vicissitudes through which Mr. Branner made his way and feels that the greatest credit is due him and his department in securing the publication of this monumental work. The printing of the report was undertaken by the Parke-Harper Company of Little Rock as a private venture actuated by the enthusiasm of Mr. Branner and encouraged by the sponsorship of the Shreveport Geological Society under the presidency of George W. Schneider.

The subject matter of the text is arranged in three parts preceded by an abstract and a bibliography and followed by an elaborate index.

In Part I "Stratigraphy and Structure," 119 pages are devoted to a discussion of the geology of the Arkansas Coastal Plain. Part II, "Oil and Gas Fields," consisting also of 119 pages, presents a concise description of the oil and gas producing fields of the area. Part III, "County by County" summarizes in 212 pages the oil and gas geology of the 46 Coastal Plain counties of the state. Such an arrangement results in an unconscionable amount of repetition, but, as each oil field and each county report is made to stand as a discrete entity, the value of the book as a reference work is thereby enhanced even though this be accomplished at the expense of its readability.

In the stratigraphic chapters, strata with an aggregate maximum thickness exceeding 10,000 feet are described both in their surface and in their underground occurrence and are correlated with the standard Coastal Plain section of the United States. The Cretaceous is regarded as a system composed of the Comanche series and the Gulf series. The Tertiary system is represented by the Eocene series only, but in the county descriptions the Pliocene (?) is also recognized. The Quaternary system, subdivided into Recent alluvium and Pleistocene Port Hudson and loess, is tabulated, but the subdivisions receive no further mention in the text.

Immediately preceding the discussion of Cretaceous stratigraphy, an account is given of the development of the Ouachita peneplain. Its present configuration, traced beneath the mantling Cretaceous formations in the deep wells of the area, is shown by means of contour lines on a plate in the pocket of the book.

The Comanche series which lies directly on the Ouachita peneplain (frequently referred to as the "Basement floor") is conceived to be made up of four groups designated as Neocomian, Trinity, Fredericksburg, and Washita. The first is unknown at the surface; the others crop out in west-central Arkansas and are widely distributed underground. Descriptions of the outcropping Comanche beds are taken largely from the papers of Miser and Vanderpool.

In the subsurface section we are told that the oldest Cretaceous sediments of Arkansas, known only in the Lion Oil and Refining Company's Hays A-9 well, deepest test in the Smackover oil field, have been tentatively correlated with the Neocomian of Texas and northern Mexico. These beds consist of red clay and sand overlying 700 feet of chalk, and in the Smackover Field at least, are underlain by more than 1,200 feet of solid salt. In the absence of decisive evidence the age of the salt has been fixed as Permian.

For the Trinity group of Arkansas, Spooner has introduced without acknowledgment the Texas formational terminology of Hill,[1] grouping the basal sands and clays in the Travis Peak formation, the middle predominantly calcareous beds with associated anhydrite in the Glen Rose formation, and the upper red clays and non-marine sands in the Paluxy. The latter is not readily separable from the upper Glen Rose and is included with that formation in the discussion. Except in the extreme southwest corner of the state the Fredericksburg and Washita groups are only meagerly represented and are entirely absent east of Red River. The author's interpretation of the

[1] R. T. Hill, "Geography and Geology of the Black and Grand Prairies, Texas." *U. S. Geol. Survey Ann. Rept. 21*, Pt. 7 (1901).

distribution of the various divisions of the Comanche series, buried beneath the Upper Cretaceous and Tertiary formations, is interestingly portrayed in a small paleogeologic map of southern Arkansas. A maximum thickness of 5,650 feet is assigned to the Trinity group. The broad features of Comanche structure in Arkansas and Louisiana are delineated on a large interval contour map (Plate XII in pocket) drawn on the base of the Glen Rose anhydrite. Partial well logs, bearing terse descriptions of cores, are included in the text; they depict the lithology of the Comanche beds in some detail.

The choice of Neocomian as a group subdivision of the Comanche series is not likely to be accorded full approval in current usage. Adkins[2] identifies the Travis Peak formation with the Upper Aptian, the uppermost Neocomian of the European section, and places the Torcer formation of southwest Texas in the Valanginian, thus leaving three of the European Neocomian stages unrepresented. In view of this correlation any Cretaceous beds occurring below the Glen Rose are necessarily of Neocomian age, but this fact does not justify the adoption of the latter term as a group name. Furthermore the Cretaceous age of the marine beds encountered in the Lion Oil and Refining Company's Hays A-9 well, Sec. 4, T. 16 S., R. 15 W., has by no means been firmly established. The only fossils found in the chalk cores from this well are obscure members of the *Miliolidae* and a few large, striated echinoid spines. Fossils from the depth of 4,972 to 5,302 feet in the Bellevue dome, Louisiana, are said by Adkins[3] to include *Polymorphina*, *Haplophragmoides*, *Haplophragmium*, *Gastropoda* and *Ostracoda;* he regards them as of either Neocomian or Jurassic age with the probabilities favoring the former. Spooner in the present treatise correlates the chalk of the Lion well with these Louisiana beds, despite their lithologic and paleontologic dissimilarities. The author's original suggestion[4] (unfortunately not repeated in the present work) that the lower part of the red section of Arkansas may be the near-shore equivalent of the Louisiana marine beds merits serious consideration. Should this idea be sustained, the chalk beds in the Lion well between the depths of 5,220 and 5,935 feet might with some assurance be assigned a Jurassic or earlier age. More extensive, deeper drilling in Louisiana and in the older Coastal Plain sediments of Arkansas and Texas will undoubtedly bring forth many surprises for the stratigrapher.

The application of the Texas formational nomenclature of the Trinity to Arkansas and Lousiana strata, long recognized as equivalents, deserves the support of all geologists. It is a distinct contribution to the geology of the Gulf-Coastal Plain.

The subdivisions of the Gulf series established by Dane[5] from his surface studies have been applied, as far as possible, to the Upper Cretaceous strata encountered in the down-dip wells of the state. Spooner has found it desirable to treat the subsurface equivalents of the Tokio formation and the Woodbine sand as forming one unit because of their lithologic similarity. The other

[2] W. S. Adkins, "The Mesozoic Systems in Texas," in "The Geology of Texas," Vol. I, *Univ. Texas Bur. Econ. Geol. Bull. 3232* (1932).

[3] *Op. cit.*

[4] W. C. Spooner, "Salt in Smackover Field, Union County, Arkansas," *Bull. Amer. Assoc. Petrol., Geol.*, Vol. 16, No. 6 (June, 1932), p. 603.

[5] C. H. Dane, "Upper Cretaceous Formations of Southwestern Arkansas," *Arkansas Geol. Survey Bull. 2* (1929).

Cretaceous formations—the Brownstown marl, Ozan, Annona chalk, Marlbrook marl, Saratoga chalk, Nacatoch sand, and Arkadelphia marl—retain their surface characteristics sufficiently to permit their recognition from well samples throughout much of the Coastal Plain portion of the state. Novel ideas are presented in the theory that the volcanic Woodbine of Ross, Miser and Stephenson[6] is of Eagle Ford or earliest Austin age and that the Tokio is to be correlated with the Tuscaloosa of Mississippi.

The thickness of the Gulf series is shown to decrease easterly from 2,000 feet in Miller County to less than 200 feet in the southeast corner of Chicot county. The maximum indicated thickness in the Upper Mississippi embayment is 800 feet. Numerous partial logs of wells giving lithologic details of the various formations add to the value of the stratigraphic discussion.

The Tertiary system, consisting of the Midway, Wilcox, Claiborne, and Jackson formations, is shown to attain a thickness approaching 5,000 feet in eastern Arkansas. Most of the discussion is taken from the earlier literature and not a few of the time-honored misconceptions of Tertiary stratigraphy are perpetuated in this section.

The structure of the Cretaceous and Tertiary beds is portrayed in some detail by means of numerous cross sections and contour maps which leave little to be desired.

In a chapter on "Structural Geology," the author summarizes his views on Arkansas and Louisiana Cretaceous and Tertiary geologic history. These views have been elaborated in earlier sections where they are inextricably interwoven with the facts of stratigraphy. The structural features briefly described are (a) the marginal monocline, (b) the Arkansas fault zone, (c) the Arkansas syncline, and (d) the Monroe uplift. These are said to be "more or less well defined structural unities" included in the great structural salient extending from the Ouachita Mountains gulfward to central Louisiana. The relationship of the local structures of the oil fields with these major features is dealt with in the ensuing description of the producing areas.

The usage of the structural term "monocline" in this discussion conforms with that commonly met with in the geologic literature of oil fields and occasions no serious confusion. It is perhaps to be regretted that in its current meaning it has taken over the function of the good word "homocline"; in accepting the change we recognize that evolution is a living force affecting language as well as organisms.

In Part II the oil fields of the state are lucidly described. Stratigraphic, structural, and statistical data derived from all available sources have been compiled and carefully worked over by the author and through these labors he has been enabled to write concise, usable reports on each of the producing areas. Fourteen oil fields with an aggregate area of 49,365 acres have been fully developed since 1921. Pipe-line runs to January 1, 1934, totaled 388,392,586 barrels; the American Petroleum Institute avers that 416,596,010 barrels were actually produced up to that date. Mr. Branner, in his letter of transmittal to the publishers, estimates that during the years 1922 to 1931, inclusive, the state of Arkansas benefitted to the extent of at least $17,000,000 through taxation imposed on the oil industry.

[6] C. S. Ross, H. D. Miser, and L. W. Stephenson, "Water-Laid Volcanic Rocks of Early Upper Cretaceous Age in Southwestern Arkansas, Southeastern Oklahoma, and Northeastern Texas," *U. S. Geol. Survey Prof. Paper 154-F* (1929).

Future production estimates, prepared by R. T. Hazzard, appear for the seven important oil fields of the state. A summation indicates that for the period between 1934 and 1940 inclusive a total of 43,971,000 barrels of pipeline oil will be produced from these pools.

In his discussion of the origin and accumulation of oil and gas, the author boldly takes his stand with the anti-migrationists, holding as his opinion that the oil of Arkansas and northern Louisiana originated where—or near where—it is now found.

In Part III, the geology of each Coastal Plain county is reviewed, the variations in stratigraphy and structure are pointed out, and most of the wildcat wells are tabulated and correlated. In the tabulations no distinction is made between producing wells and dry holes, but comparatively few of the former are listed. In all, 936 wells appear in the county reports. This is only a small percentage of the actual number bored. One company report shows that at the end of 1934, a total of 8,084 wells had been drilled in southern Arkansas, of which 6,004 were oil wells, 312 produced gas, and 1,768 were dry holes. Among the few errors which have crept into the tabulated well data, B. W. Blanpied[7] has pointed out that a test listed in St. Francis County (5. Arkansas Nat. Gas Company, Swearingen No. 1) was actually drilled near Jackson, Hinds County, Mississippi. On the whole, however, the well lists are accurate and convenient. The counties are arranged alphabetically and an index map accompanies the text, which shows the location of test wells and, in most cases, contours have been drawn on the top of the Nacatoch sand.

In considering the possibility of the discovery of new producing areas, the author has chosen to be ultra-noncommittal. There is but cool comfort for the intrepid seeker after new reserves to be found in the "map showing oil and gas possibilities in the Gulf Coastal Plain in Arkansas" (Fig. 19, p. 152). It merely shows this portion of the state divided into four areas, each embracing several counties, in which future prospects may be considered fair in Area 1 (southern Coastal Plain), poor in Area 2 (central Mississippi Embayment), very poor in Area 3 (Cretaceous outcrop), and *nil* in Area 4 (thin sediments skirting Paleozoic contact). The potentialities of the Paleozoic formations buried beneath the coastal sediments in Areas 2 and 4, recently accorded vigorous acclaim by Crider,[8] have been ignored by Spooner.

The practical reader in his first scurry through the leaves of the book may feel that he has struck pay dirt when on page 133 he is told that "it seems probable that local fields of considerable magnitude may be present," but to his chagrin he presently discovers in the table of errata that for "fields" he is to read "folds." *Sic transit gloria mundi.*

To some the lack of paleontologic data may appear to be a serious shortcoming in the work; to others the omission of many formidable faunal lists will come as a pleasant surprise granting surcease from the responsibility of scrutinizing the inscrutable. But the average reader would probably feel that he had been taken more fully into the writer's confidence were he given the names of a few more of the guide fossils by means of which the important correlations have been made. The assuagement of such sentiment was at-

[7] Personal communication.

[8] A. F. Crider, "Potentialities in Northeastern Arkansas," *Oil and Gas Journal*, Vol. 32, No. 48 (April 10, 1934).

tempted in the inclusion of a reprint of M. C. Israelsky's valuable study of the "Upper Cretaceous Ostracoda of Arkansas" as an appendix.

The lack of careful editing, evidenced by such errors as the statement on page 148 that "beds strike northwest and dip in an easterly to southeasterly direction," the bad addition on page 170 where the whole is made to appear less than the sum of its parts, the inclusion of a Reklaw (lowest Claiborne) well record in the discussion of the Jackson formation, and others, makes alert reading necessary. Some of the figures, particularly the production curves, have suffered somewhat in the process of reduction, but the numerous plates in the pocket are clearly printed and form a valuable addition to any geologic library.

The critical reader will be annoyed by the unusually large number of typographic errors that mar the composition and will occasionally find himself fatigued by a tedious repetition, but when at last he has completed his study of the book he will be in possession of a sound working knowledge of the oil and gas geology of the Coastal Plain of Arkansas.

C. L. MOODY

SHREVEPORT, LOUISIANA
March 5, 1935

RECENT PUBLICATIONS

CALIFORNIA

"Fossils from the Marine Pleistocene Terraces of the San Pedro Hills, California," by W. P. Woodring. *Amer. Jour. Sci.* (New Haven, Connecticut), 5th Ser., Vol. 29, No. 171 (March, 1935), pp. 292–305; 1 map.

FRANCE

"Le pétrole en France, 1927–1934" (Petroleum in France, 1927–1934), by Ch. Finaton. *Rev. Petrol.* (Paris), No. 616 (February 2, 1935), pp. 139–42; 4 figs.

GENERAL

"Einfache Geräte zum Fotografieren von Mikrofossilien, insbesondere Foraminiferen" (Simple Equipment for Photographing Microfossils, Especially *Foraminifera*), by Franz Hecht. *Senckenbergiana* (Frankfurt a. M.), Vol. 16, No. 2–3 (October 5, 1934), pp. 65–77; 11 figs. and photographs.

Mining Year Book, compiled by Walter E. Skinner. International standard reference work on mines. To be obtained from Walter E. Skinner, 15, Dowgate Hill, London, E. C. 4. Price, 21s. 6d, postpaid.

GEOPHYSICS

"Aufsuchen von erdölhöffigen Strukturen durch Massung des scheinbaren spezifischen Widerstandes" (Search for Oil Structure by Measurement of Apparent Specific Resistivity), by A. Belluigi. *Petrol. Zeit.* (Berlin), Vol. 31, No. 5 (February 1, 1935), pp. 1–2; 3 figs.

"Das neue Gravimeter der Seismos G.m.b.H., Hannover, zur Aufsuchung und Begrenzung unterirdischer Dichtestörungen" (The New Gravimeter of Seismos, Hannover, for Locating Dense Subsurface Masses), by St. v. Thyssen. *Petrol. Zeit.*, Vol. 31, No. 5, pp. 2–3; 1 fig.

"Eine neue Apparatur für seismische Bodenforschung nach dem Piezo-Quartz-System" (New Equipment for Seismic Soil Investigation by the Piezo Quartz System), by Richard Ambronn. *Ibid.*, pp. 4–8; 6 figs.

"A Study of Some Seismometers," by G. A. Irland. *U. S. Bur. Mines Tech. Paper 556* (1935). 49 pp., 25 figs. Price, $0.10.

GERMANY

"Die erdölhöffigen Gebiete Deutschlands" (Prospective Petroleum Regions in Germany), by Wilhelm Georg Simon. *Zeit. prak. Geol.* (Wilhelm Knapp, Halle, Saale), Vol. 43, No. 1 (January, 1935), pp. 10–14; 3 figs.

"Ist die Kolbitz-Letzlinger Heide erdölhöffig?" (Is the Kolbitz-Letzlinger Forest Oil-Bearing?), by Hermann Schröder. *Petrol. Zeit.* (February 1, 1935), pp. 10–11; 1 fig.

"Die erdölgeologische Literatur Deutschlands bis 1933" (The Literature on the Petroleum Geology of Germany to 1933), by B. Beschoren. *Preuss. Geol. Landesanstalt Archiv. für Lagerstättenforschung, No. 60* (Berlin, 1934). 91 pp.

WASHINGTON

"Oil and Gas Possibilities of Western Whatcom County," by Sheldon L. Glover. *Washington Dept. Conservation and Dev., Div. Geol., Rept. Investigations 2* (Pullman, 1935). 69 pp., 1 pl., 1 fig.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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Edward W. Scott, Bell, Calif.
Desaix B. Myers, Harold W. Hoots, E. K. Soper

John Joseph Simkins, Dallas, Tex.
F. L. Whitney, Fred M. Bullard, J. C. Pollard

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

DONALD GOODWILL, JR., of the Louisiana State Department of Conservation, has moved from Shreveport to 126 Civil District Court Building, New Orleans, Louisiana.

MAXIM K. ELIAS, of the Kansas Geological Survey, Lawrence, Kansas, read a paper on Western Kansas before the Kansas Geological Society at Wichita in February.

PAUL A. SCHLOSSER, geologist with Phillips Petroleum Company, has moved from San Angelo to Midland, Texas.

A. E. FATH, Semperhaus B/III, Hamburg 1, Germany, was in the United States in February.

JOHN L. RICH, associate professor of geology at the University of Cincinnati, Ohio, gave a series of radio talks in February and March on "Oil and Gas," including origin, distribution, reserves, waste, and the future. Mimeographed copies of these talks will be mailed by the University on receipt of five cents each in stamps or coin.

JAMES D. SISLER, former state geologist of West Virginia, is consulting geologist for the Carnegie Gas Company at Pittsburgh, Pennsylvania.

CLARK F. BARB, associate professor of petroleum engineering, Colorado School of Mines, Golden, Colorado, has taken a leave of absence until September 15, 1935, to carry on geological and engineering investigations in Pennsylvania for the Sloan and Zook Company of Bradford, Pennsylvania.

L. S. BROWN, of Massachusetts Institute of Technology, will direct the work to be done under a grant of $1,000 made by the National Research Council to the department of chemical engineering at the Institute.

A. E. ALEXANDER, formerly petrographer with the Spencer Lens Company, Buffalo, New York, has been appointed research associate in mineralogy and petrography by the Buffalo Museum of Science.

E. W. K. ANDRAU, formerly chief subsurface engineer with the Shell Petroleum Corporation at Houston, announces the opening of a consulting office at 221 Shell Building, Houston, Texas, specializing in Schlumberger interpretations and oil-field subsurface and exploration problems including valuations and appraisals.

The annual meeting of the Alberta Society of Petroleum Geologists was held on January 26, 1935, and the following officers elected: president, T. B. WILLIAMS; vice-president, R. V. JOHNSON; secretary-treasurer, F. M. STEEL; and business representative, H. M. HUNTER. The following papers were read: (1) "Blairmore Formation of Northwestern Montana," by J. S. IRWIN; (2) "Comparison of Blairmore and Belly River Formations of Alberta Foothills,"

by J. G. SPRATT; (3) "Comparison of Mesozoic Formations in Central Saskatchewan and Eastern Alberta," by J. O. G. SANDERSON; (4) "Willow Creek Formation," by H. M. HUNTER; (5) "Structural Growth of Sweetgrass Arch, as Inferred from Isopachs," by J. S. IRWIN; (6) "Foothills Map and Types of Foothills Structure," by R. WILLIS; (7) "Progress in Cutbank Oil and Gas Field, Montana," by J. S. IRWIN; and (8) "Occurrence of Anhydrite in Alberta," by R. M. S. OWEN.

LINN M. FARISH, formerly with Henry L. Doherty and Company, New York City, is now with the Sinclair Prairie Oil Company, Tulsa, Oklahoma.

R. B. GRIGSBY, geologist with the Stanolind Oil and Gas Company, has changed his address from Baton Rouge to Lake Charles, Louisiana.

E. B. WILSON, geologist for the Sun Oil Company, has been transferred from Tyler to San Angelo, Texas.

MILO M. ORR, formerly an independent geologist at Laredo, Texas, is now associated with the Superior Oil Company of California, and has opened offices at Laredo. He will be in charge of the company's operations in southwest Texas.

CHARLES E. DECKER, professor of geology at the University of Oklahoma, and an honorary member of the Association, was recently elected president of the Oklahoma Academy of Sciences.

MORTON T. HIGGS, formerly of Houston, Texas, is representing the Sperry-Sun Well Surveying Company of Philadelphia, Pennsylvania, in Kansas, Oklahoma, and Arkansas, and has established offices at 425 Petroleum Building, Tulsa, Oklahoma.

L. G. MORGAN is a new member of the geological department of the Vickers Petroleum Company, of Wichita, Kansas.

GEORGE D. MORGAN, president of the Cardinal Oil Company, San Angelo, Texas, has been appointed a member of the University of Texas board of regents by Governor Allred.

DALE DARRELL SPARKS has changed his address from 4151 Normal Avenue, Hollywood, California, to Petroleum Building, Houston, Texas.

M. H. STEIG, geologist with the Shell Petroleum Corporation, has been transferred from San Antonio to Houston, Texas.

RALPH O. RHOADES, formerly of the Gulf Companies, Pittsburgh, Pennsylvania, may now be addressed in care of the Kuwait Oil Company, Kuwait, Persian Gulf.

JOSEPH M. PATTERSON, geologist with The Texas Company, has changed his address from Corsicana to Houston, Texas.

H. W. BELL, geologist with the Lion Oil Refining Company, formerly located at Houston, Texas, is now with the same company at El Dorado, Arkansas.

E. W. HARD, formerly of Buffalo, New York, is now with The Texas Company, 306 Masonic Building, Shawnee, Oklahoma.

H. R. THORNBURGH, geologist with the Shell Petroleum Corporation,

has changed his address from 2505 Virginia, Berkeley, California, to 1820 Bolsover, Houston, Texas.

LESTER A. LUECKE, formerly chief geologist for the Columbian Petroleum Company, in Cucuta, Colombia, S. A., has recently been added to the geological staff of the Gulf Corporation, Pittsburgh, Pennsylvania.

W. DOW HAMM, geologist for the Shell Petroleum Corporation, Houston, Texas, has gone to The Hague, Holland, on company business, where he will remain for approximately a year. His address is 30 Carel van Bylandtlaan.

ROY LEBKICHER, formerly at 225 Bush Street, San Francisco, California, may now be addressed in care of L. N. Hamilton, 6 Lothbury, London, E. C. 2, England.

BELA HUBBARD has changed his address from the Carter Oil Company, Tulsa, Oklahoma, to the Standard Oil Company of New Jersey, 30 Rockefeller Plaza, New York City.

The San Antonio Geological Society held its regular monthly meeting March 4 at the Petroleum Club, and a symposium on "Aerial Photography and Its Geologic Interpretation" was presented.

SAM KORNFELD, consulting geologist, has opened an office at 904 Kennedy Building, Tulsa, Oklahoma.

At a meeting of the Tulsa Geological Society, March 4, E. B. Branson presented the following paper: "Subaerial Deposits as Illustrated by Permian, Triassic, and Cretaceous Formations."

J. A. TONG has given up consulting work in Venezuela and has become associated with the Socony-Vacuum Oil Company with headquarters in Caracas, Venezuela.

JOHN C. POOLE, formerly with the Superior Oil Producing Company, Lafayette, Louisiana, is now with the Barnsdall Oil Company, Houston, Texas.

CECIL V. HAGEN, formerly with the Feltex Oil Corporation, Houston, Texas, is now with the Eastland Oil Company of Fort Worth, and is located at San Antonio, Texas.

CHESTER D. WHORTON, geologist for Godfrey L. Cabot, Inc., has moved his office from Coudersport, Pennsylvania, to Olean, New York.

FRED E. JOEKEL is now employed as geologist for the Magnolia Petroleum Company, Dallas, Texas.

R. E. RETTGER, geologist with the Sun Oil Company, and formerly at San Antonio, is now in the office at Dallas, Texas.

C. E. BURBRIDGE, JR., has changed his address from The Texas Company, Houston, Texas, to Cia. Minera de Peñoles, Apt. 251, Monterrey, N. L., Mexico.

At a recent meeting of the San Antonio Geological Society, the following officers were elected: president, JOSEPH M. DAWSON; vice-president, PHILIP

S. SCHOENECK; secretary-treasurer, ADOLPH DOVRE. IRA O. BROWN was elected a member of the executive committee.

A. A. HUNZICKER, formerly of Houston, Texas, is now located at Palestine, Texas, as computor on a seismograph crew for The Texas Company.

L. C. HOOKWAY, formerly at Moorpark, California, may now be addressed at 21 East Washington, McAlester, Oklahoma.

R. P. LOCKWOOD has been transferred from the geological department of the Gypsy Oil Company to the Gulf Research and Development Company. His address is Box 373, Eads, Colorado.

PAUL S. OLES, formerly geologist for the Sinclair Prairie Oil Company, has been named president of the newly organized Pine Rock Oil Company, at Midland, Texas.

E. J. BOOS has been appointed resident geologist for the Phillips Petroleum Company in Colorado, and has established headquarters in Denver.

G. C. POTTER is associated with the D. D. Oil Company, at Mission, Texas.

DAVID DONOGHUE is the author of a brief article, "The Technical Witness," in *The Journal of Accountancy* of March, 1935.

H. K. SHEARER, of the Pelican Natural Gas Company, should now be addressed in care of The Hunter Company, Inc., Box 532, Shreveport, Louisiana. This is merely a change in the name of the company.

IVAN J. FENN is working for the Independent Exploration Company of Houston, Texas.

The Kansas Geological Society announces its ninth annual field conference in coöperation with the State Geological Surveys of Iowa, Illinois, Wisconsin, and Minnesota. The trip, lasting eight days from Sunday, August 25, to Sunday, September 1, 1935, and beginning at Iowa City, Iowa, and ending at Duluth, Minnesota, is arranged for a comprehensive examination of the pre-Mississippian sediments of eastern Iowa, northwestern Illinois, central and western Wisconsin, and eastern Minnesota with special emphasis on the Ordovician and Cambrian systems. Reservations and orders for the *Guidebook* should be sent to Anthony Folger, chairman of the committee on arrangements, Gypsy Oil Company, 1107 Union National Bank Building, Wichita, Kansas.

At the regular meeting of the Rocky Mountain Association of Petroleum Geologists held at the Auditorium Hotel, April 1, at Denver, Colorado, J. HARLAN JOHNSON presented the following paper: "Stratigraphy of South Park, Colorado."

J. C. LEGRAND, of the Schlumberger Well Surveying Company, addressed the North Texas Geological Society, March 29, 1935, on the work of his organization.

At a meeting of the San Antonio Geological Society at the Petroleum Club on Monday night, April 1, a paper "The Tuleta Oil Fields and Adjacent Area" was presented by FRED P. SHAYES.

MAX STEINEKE has been transferred from the Bakersfield office of the Standard Oil Company of California to do geological work in Saudia, Arabia,

for the subsidiary California Arabian Standard Oil Company, with headquarters at Jubail, Al Hasa.

GEORGE C. BRANNER, State geologist of Arkansas, Little Rock, is president and ARTHUR BEVAN, State geologist of Virginia, is secretary of the Association of American State Geologists. RAYMOND C. MOORE, State geologist of Kansas, is a new member of the executive committee.

C. MAX BAUER, park naturalist, has a brief article on "Abstract Geological Research in Yellowstone National Park," in the *Inland Oil Index* (Casper, Wyoming) of March 22.

H. D. EASTON, of Shreveport, Louisiana, is the author of an illustrated paper entitled, "North Louisiana Surface Structure Evidence is Small," in the *Oil Weekly* of March 25.

ARTHUR WADE is engaged in geological exploration in the state of Western Australia.

A. D. MILLER has resigned as manager of the southwest Louisiana branch office of the Louisiana Conservation Commission Minerals Division at Lake Charles.

WILLIAM B. HEROY, past-president of the Association, has been elected a director of the American Institute of Mining and Metallurgical Engineers. HENRY A. BUEHLER, State geologist of Missouri, is president of the Institute.

The mid-year meeting of the American Petroleum Institute will be held at Tulsa, Oklahoma, May 14–16.

E. G. WOODRUFF, consulting geologist of Tulsa, has an article on "Natural Asphalts in Use Long Before They Were Refined from Crude Oil," in the *Oil and Gas Journal* of March 28.

H. D. EASTON writes on "Volcanoes of Northeastern Louisiana Account for Accumulation of Oil" in the *Oil and Gas Journal* of March 28.